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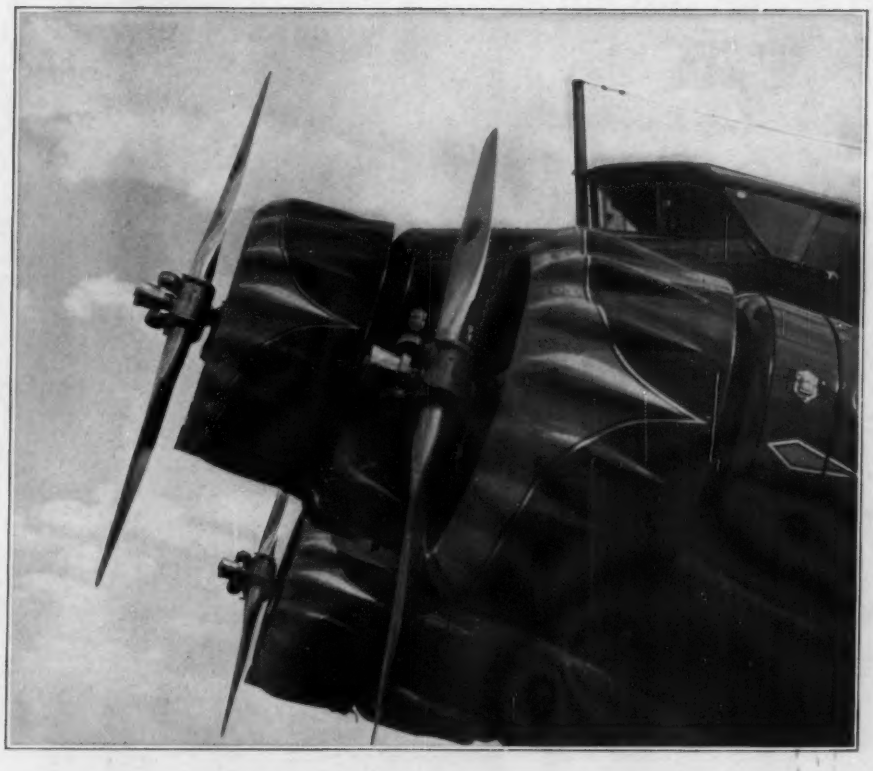

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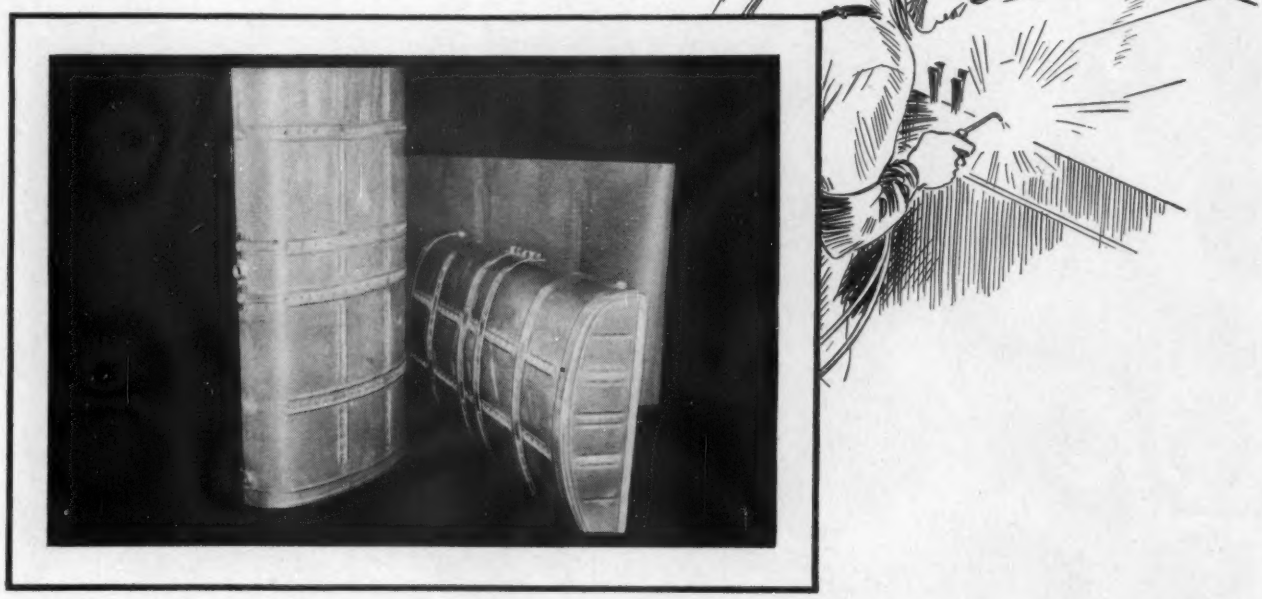

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PROFESSOR CHARLES F. TAYLOR, who wrote *Engines in Modern Aircraft*, is Professor of Automotive Engineering in charge of instruction and research in Internal Combustion Engines at Technology. In 1915 he received a Ph.B. degree from the Yale Sheffield Scientific School, and in 1920 an M.E. degree. For a time he was in charge of airplane engine design and development in the Wright Aeronautical Corporation. During the summer of 1931 he was sent to Japan to give a series of lectures to officers and civilian engineers of the Imperial Japanese Navy.

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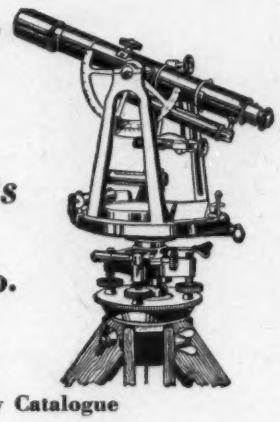

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DECEMBER, 1936
VOLUME XVII
NUMBER 7

CONTENTS

THE COVER — POWER
Photo by—Robert F. Driscoll, '37

FRONTISPIECE—SCHEDULED DEPARTURE
Photo by—Will B. Jamison, '39

ENGINES - - - - - - - - - - 159
By Professor C. Fayette Taylor

ENGLISH AIRCRAFT INDUSTRY - - - - 161
By C. G. Grey

WING CONSTRUCTION - - - - - - - 164
Courtesy—*Aero Digest*

AIRCRAFT MANUFACTURERS - - - - 165
By S. Paul Johnston, '21

INSTRUMENTS - - - - - - - - 170
By Professor Charles S. Draper, '26

PROPELLER DESIGN - - - - - - - 172
By Frank W. Caldwell, '12

EDITORIALS - - - - - - - - - 174

TREND IN AVIATION
By George F. McLaughlin

AERONAUTICS AS A FIELD OF ENGINEERING
By Professor Richard H. Smith

ENGINEERING DIGEST - - - - - - - 176

RESEARCH IN REVIEW - - - - - - - 177

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Technique

SCHEDULED DEPARTURE

A Discussion of

ENGINES

In Modern Aircraft

By PROFESSOR C. FAYETTE TAYLOR
Professor of Automotive Engineering, Massachusetts Institute of Technology

THERE has been a rather widespread belief that the modern airplane engine is merely an outgrowth of the automobile engine, and that it owes a great deal of its present refinement to experience gained in the automobile field. As a matter of fact, the development of the airplane engine started almost simultaneously with that of the automobile engine and, while the two have continued to use the same general principles of operation, airplane engine development has followed a path which is in many respects quite distinct from that of automobile engine development. For example, in the year 1903, the only two aeronautical engines in existence, namely, those built by the Wright brothers, and by C. M. Manley for the Langley "Aerodrome," represented a higher degree of refinement and were much further on the way to modern aeronautical practice than any automobile engine then in existence.

Development of airplane engines since the pioneer period has been in the nature of refinement in detail rather than radical change. Ever since power flight in heavier-than-air machines has been under consideration, certain special requirements for the power plant of such machines have been very evident. The importance of reliability admits of no argument, since the airplane is utterly dependent on continuous functioning of the power plant. Next to reliability, light weight of engine and fuel in proportion to the effective power output is the distinguishing requirement imposed on the airplane engine.

Power Plant Weight

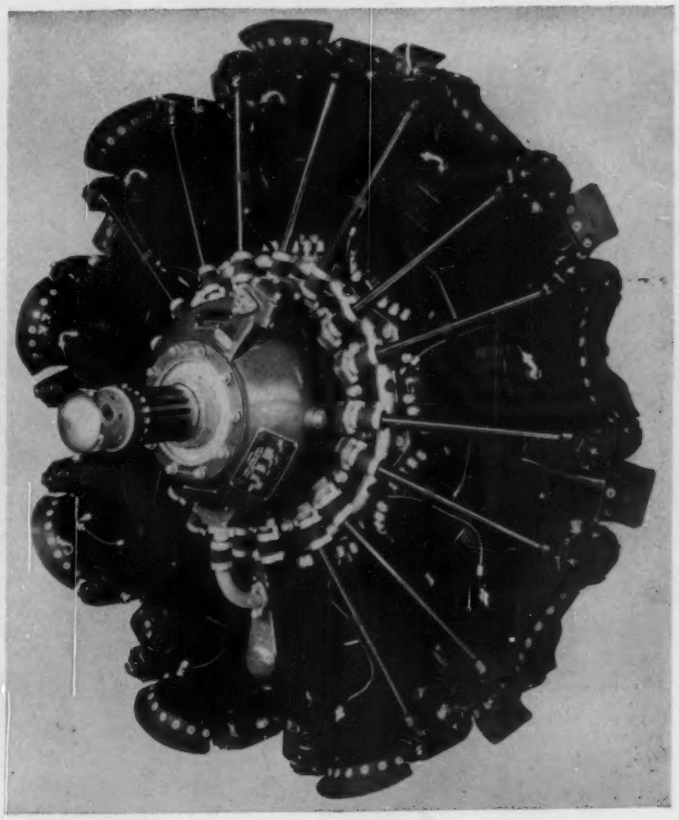
The present limits on total weight of an airplane range from six pounds per horsepower for high-speed military pursuit machines to seventeen pounds per horsepower for long-distance transport planes. Obviously, the complete power plant with its fuel must weigh only a fraction of these values, in order that carrying capacity may be available for the airplane structure itself, and for its useful load. Usually the weight of the airplane structure is more or less fixed by the particular design problem in hand, which means that any increase or decrease in power-plant-plus-fuel weight is immediately reflected in a corresponding increase or decrease of the useful load which may be carried. In this connection it is interesting to consider that a modern airplane engine will consume the equivalent of its own weight in fuel in from three to five hours of operation. Thus, for long-distance flights the weight of fuel is a larger item than the weight of the engine itself.

The output obtainable from an internal combustion engine is proportional to the rate at which it can pump air through its system, and the efficiency with which it can burn the mixture consisting of this air with its attendant fuel vapor. Emphasis is placed on air-handling ability because of the insignificant volume (about two percent) occupied by the fuel vapor necessary to impart to the mixture its maximum energy value.

One of the obvious ways to increase the output without increasing the size and weight of a given engine is to increase the crankshaft speed, thereby increasing the rate of air consumption per unit time and the possible output obtainable. When this process is carried very far, a point is reached at which the air consumption no longer increases but rather falls off as the speed goes higher. If additional output is required, it is necessary to increase the "breathing" capacity of the engine, either by increasing the size of the inlet passages and valves, or by introducing a "supercharger" or pump to supplement the engine's own air-pumping ability. The normal speed of one important American engine has been increased during the last decade both by improving the valve and port design, and by supercharging.

When a supercharger of appreciable capacity is used, the output of the engine may no longer be limited by its air-handling capacity. Quite often the limitation then encountered is that of cooling the cylinders and exhaust valves. If this is the case, output may be raised as cooling effectiveness is improved. In the case of the engine previously mentioned, this has been done by progressively increasing the cooling-fin area, and by improving the arrangement of cowling and baffling used to guide the air through the inter-fin spaces. A remarkable fact is that this very large increase in cooling capacity has been achieved with a considerable *reduction* in the resistance, or "drag," of the power plant. The type of cowl used has been developed chiefly through the efforts of

—*Courtesy Aero Digest*



New 1000 horsepower Wright cyclone, R-1820-G.

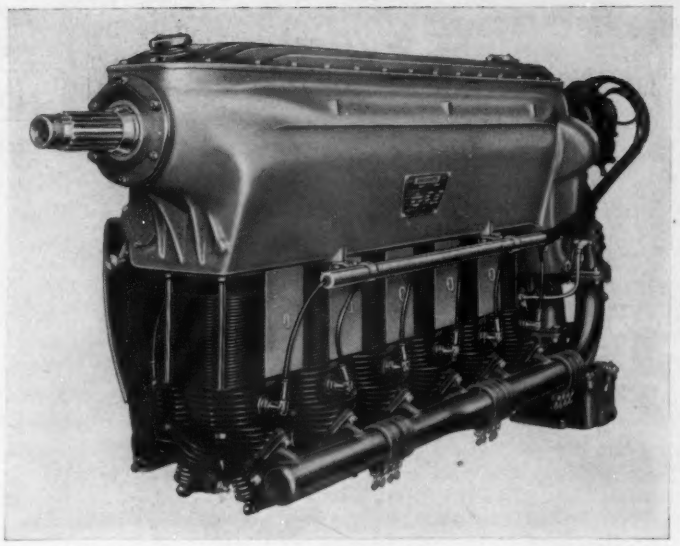
the U. S. National Advisory Committee for Aeronautics. The development of this type of cowling has been a major factor in the remarkable increase in average airplane speed which has occurred in the last three years.

In addition to these improvements in cooling-fin area and baffling, the cooling of the exhaust valve has been greatly improved by partly filling the hollow valve with metallic sodium. At running temperatures the sodium becomes liquid and as it is thrown back and forth by the valve motion, it assists in conveying heat from the valve head to the stem, where it can flow off through the valve guide to the cooling fins.

Another limitation almost always encountered when power is increased by supercharging, is the type of combustion known as "detonation". This may have destructive effects on the engine parts, and cannot be tolerated for long-continued periods of operation. The limits imposed by detonation have steadily been raised by improvements in the quality of fuels available for aircraft. Such improvements have made possible not only significant increases in engine output per unit of weight and size, but have also allowed compression ratios to be increased with corresponding improvements in efficiency and lowering of fuel consumption.

Another limitation which has been encountered in attempts to increase engine output is that of mechanical stresses in engines. This limitation has been steadily reduced by the improvement in the quality of materials available and the experience of designers in achieving economical distribution of material in the various engine parts.

The result of such efforts has been a steady reduction in the ratio of power plant weight to output of the typical American airplane engine, from about five pounds per horsepower in 1918, to about two pounds per horsepower at the present time, the engine alone weighing in many cases not over one



—*Courtesy Menasco Manufacturing Co.*

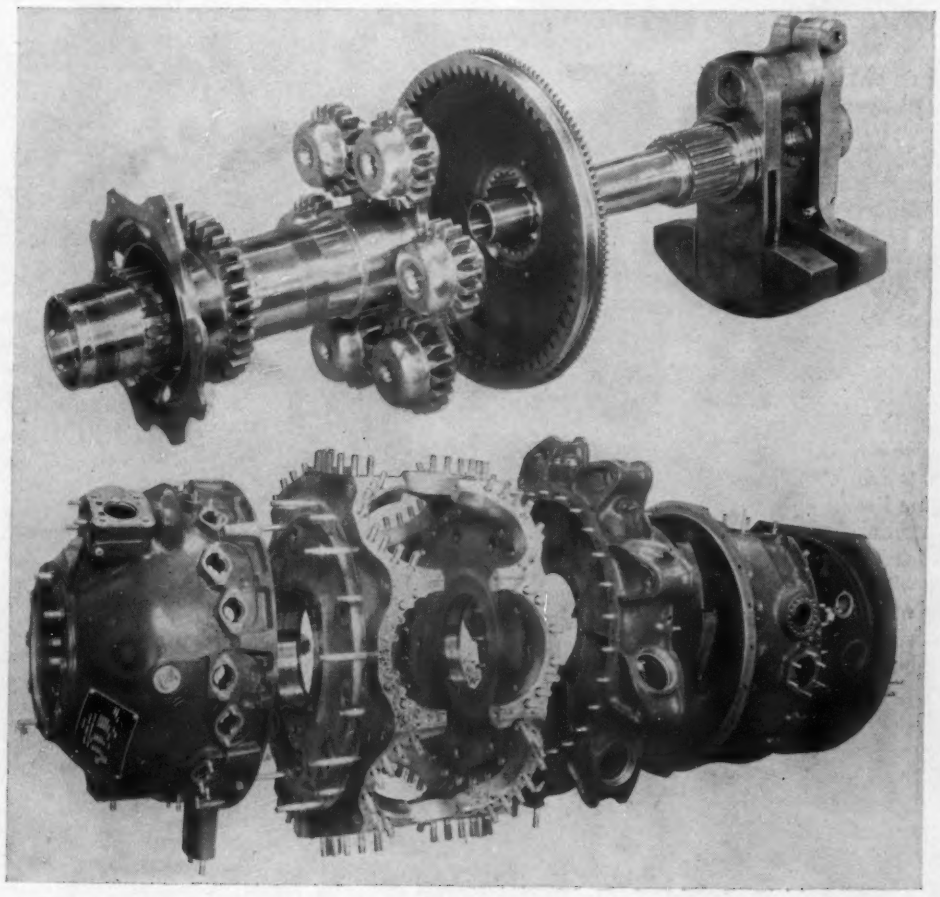
200 horsepower Menasco B-6-S.

and one-tenth pounds per maximum horse power.

Reliability

At the same time that these significant advances in power-weight ratio have been taking place, the reliability of airplane engines has increased enormously. Power plant failures in flight are extremely rare and, in addition, the period between necessary overhauls has increased from about 50 hours of flying in 1918 to an average of 400 hours at the present time.

—*Courtesy Aero Digest*



Typical Modern Engines

Modern airplane engines can be divided roughly into two classes. The first class consists of engines used for training, private and miscellaneous flying. These are mostly of relatively small size (40 to 300 horsepower). In the second class fall engines used for the military service and for regular airline operation, which in this country range from 400 to 1000 rated horsepower.

In the first classification, first cost is a sufficiently important factor so that weight and fuel economy can be sacrificed to some extent if cost can be reduced thereby. Low fuel consumption is relatively unimportant, because such service is generally confined to flights of short duration. In general, American airplane engines in this class are air-cooled and of simple form, with relatively few cylinders. Typical examples are the Continental four-cylinder, opposed, forty horse-

(*Continued on page 178*)

Wright Cyclone G crank-shaft assembly and crank-case section.

A Description of the

ENGLISH AIRCRAFT INDUSTRY

As It Exists To-day

By C. G. GREY
Editor of The Aeroplane

AERONAUTICAL Engineering in England today is more interesting than it has ever been. In this country we are trying to do three different things at once. We are trying to build up some sort of technique in the production of civil aeroplanes for normal peace time air transportation of passengers, freight, and mail. We also believe that we are producing the world's best fighting aeroplanes, with the finest all round performance in speed, rate of climb, and load carried. Over and above that, we are trying to develop the mass-production of aeroplanes, and particularly of aero-motors, to meet the demands in the Air Ministry (a) for the immediate expansion of the Royal Air Force and (b) for the building up of a reserve of production in case of the outbreak of war.

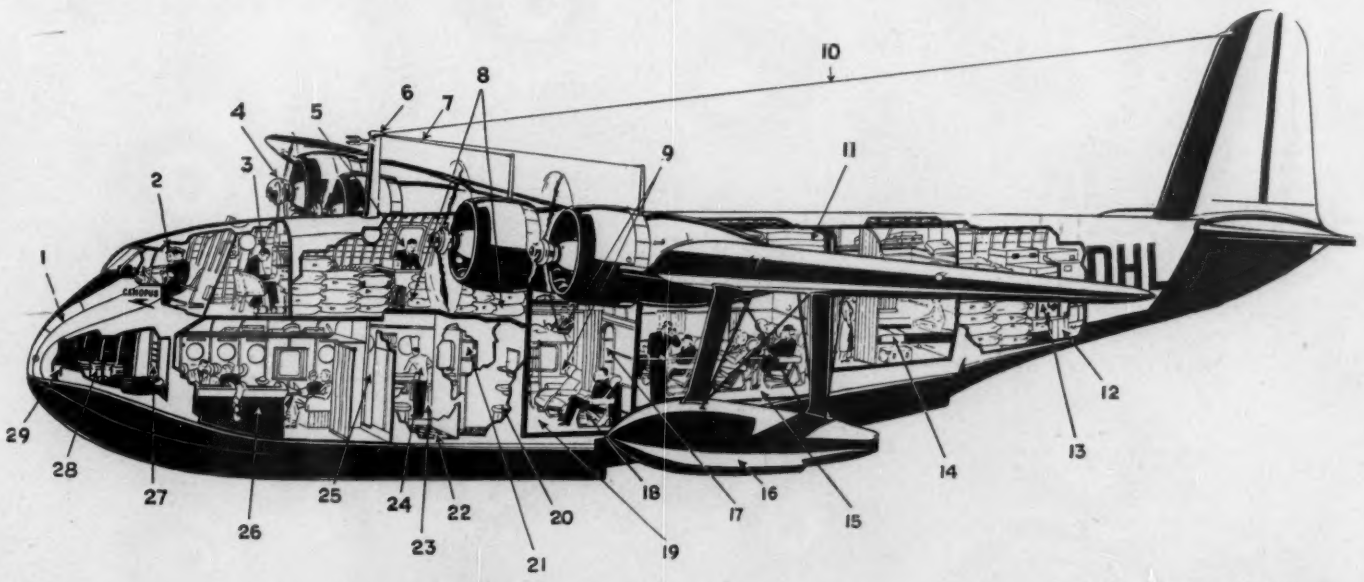
Each of those three lines of development is interesting, and, if only we could cut the British Aircraft Industry into three watertight compartments, and have each department develop aeroplanes only along its own line, everything would be beautiful. But unfortunately the Air Ministry has insisted on mixing up the whole lot to such an extent that we are in a delightful state of chaos, and nobody knows quite where we are today and where we are likely to be tomorrow.

Naturally nobody is in business for his health, and therefore everybody in the Aircraft Industry wants to make money while the Air Force is expanding,—a modern version of making hay while the sun shines. And so everybody who can make what the Air Ministry wants, whether complete aeroplanes, or complete motors, or bits and pieces and parts thereof, is, so to speak, sitting on the doorstep of the Air Ministry begging for orders. The result is that the efforts of quite well-equipped factories and quite capable young aeronautical engineers are turned to duplicating parts of war-machines which were designed as complete units six or seven years ago, when the brains of these engineers and the equipment of the factories ought to be busy today producing new types of very modern aeroplanes.

About the only aircraft factory in Great Britain today which is devoted entirely to the production of civil aeroplanes is that of Short Brothers (Rochester & Bedford) Ltd., of Rochester, which has just turned out the first two of our great Empire flying-boats, each of which has four 920-horsepower Bristol Pegasus motors. Twenty-eight of them have been ordered, and unless something needs altering, orders for another twenty-five or thirty similar ones will undoubtedly be forthcoming.

People talk in almost awe-struck tones of these great Empire flying-boats which weigh over eighteen tons apiece and have a total of 3,680 horsepower. But when one realizes what a tiny thing a twenty-ton yacht or fishing-boat really is, one begins to see how, if aeronautical engineers are to keep themselves abreast with progress, they must cast their ideas ahead to flying-boats of well over a hundred tons.

When once they start doing that they come up against the motor problem. The biggest aero-motors in general service



—*Courtesy Aviation*

SECTION OF SHORT EMPIRE "CANOPUS"

(1) Mooring hatch; (2) pilots' compartment; (3) radio operator; (4) rotable loop antenna; (5) ship's clerk; (6) mast-head light; (7) vee aerial; (8) mail compartments; (9) sleeping berths; (10) fixed aerial; (11) hold for bedding; (12) mail and baggage hold; (13) trailing edge flaps; (14) after cabin (six day passengers, four at night); (15) promenade cabin (eight by day, four by night); (16) wing tip float; (17) main gangway; (18) adjustable chairs; (19) mid-ship cabin (three by day, four by night); (20) women's lavatory; (21) gang-way to upper deck; (22) men's lavatory; (23) kitchen; (24) steward; (25) passage- way from main entrance; (26) smoking cabin (seven by day, four by night); (27) gangway to control room; (28) mooring compartment; (29) retractable landing light.

today have about 950 horsepower, and there are a few, which have not entirely proved their reliability, which have about 1,400 horsepower. If we are to have a flying-boat or landplane of a hundred tons, then we must have motive power of about 15,000 horsepower. And as the use of more than four separate motors is likely to cause dangerous complications, some bright engineer will have to devise a single aero-motor which will give more than 4,000 horsepower. So the next problem is how to produce single power-plants of 4,000 horsepower or thereabouts.

Apart from Short Brothers, various firms which have lately made a name for themselves as designers and producers of small high-speed civil aeroplanes, such as the Percival Gull series and the Miles Hawks, Falcons and so forth, have been doing some real aeronautical engineering. But, sad to relate, Phillips & Powis, who build the Miles Hawk, are gradually being seduced into making training-ships for the R.A.F., and they have also produced particularly pleasing twin-motor, light, fast transport ships which have two 200 horsepower six-cylinder Gipsies, or a couple of Menascos of about the same power, which unfortunately will probably be adopted by the Air Force and made into fast coastal-reconnaissance machines, or may be developed in all-metal structures and turned into two-motor two-seater fighters.

The De Havilland Aircraft Co., Ltd., which started off deliberately to cut loose from the Air Ministry and made an enormous name for itself with its Moth series of light aeroplanes, including the Puss Moth and Leopard Moth cabin ships, started in two or three years ago to make twin-motor transport ships to carry eight passengers and four-motor ships to carry sixteen passengers. Then they made the famous twin-motor Comet, which won the England-to-Melbourne Air Race in 1934, and now they are being ruined by the Royal Air Force.

They started by making the Tiger Moth as a trainer. Then they sold several of their twin-motor ships to the R.A.F. to be used for the transportation of officers. Then somebody fitted an ordinary Moth with an automatic gyro-pilot and radio control and turned respectable little two-seat biplanes into targets for gunners of the Royal Navy.

I am not a wireless shark so I am not in a position to say anything about the control devices, but I believe they work very well and the Queen Bee can be got off the water and brought down on it if the water does not happen to be very rough. Fortunately the Navy hardly ever succeeds in hitting one of these expensive targets and in bringing it down. If naval gunnery were better, more time would have to be spent on

—*Courtesy Aviation*

New Westland army co-operation plane.

building mere targets for the Navy, instead of using that time producing progressive civil aeroplanes.

For the time being the bigger De Havilland air liners are still being used exclusively for civil work, but nobody knows when the whole output will be taken over by the Air Force.

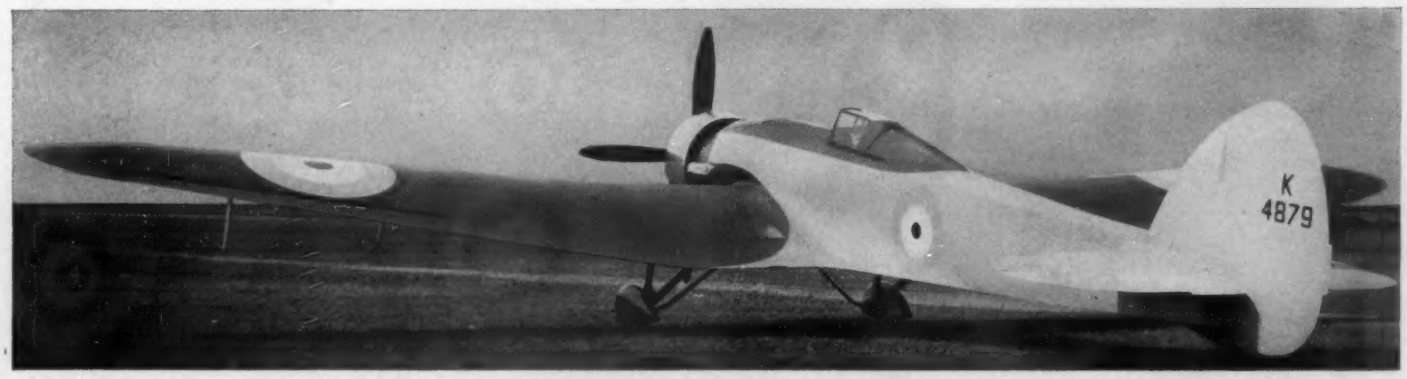
The result of all this is that just now, when trade all over the British Empire is expanding and air transport is badly needed to speed up trade, there is not one firm left free to modify civil transport machines to suit the requirements of customers overseas.

The natural assumption is that the U. S. Aircraft Industry and probably the German will get the orders which normally should go to British manufacturers of transport ships, and that when the expansion scheme for the R.A.F. has been stretched to the elastic limit and the R.A.F. is full of more-or-less obsolete aeroplanes, our manufacturers will awaken rudely to the fact that other countries have got the world's air transport trade.

So far as our manufacturers of war machines are concerned we have every reason to be satisfied with the present state of affairs. The Rolls-Royce water-cooled motors have proved themselves to be far ahead of any others in the world on a basis of pounds of weight per horsepower delivered. The Bristol Pegasus motor, which has just finished an Air Ministry type-test at 1,000 horsepower, is now claimed to work out at one pound per horsepower and to be at the same time the cheapest unit for its horsepower in the world.

Also the new Bristol sleeve-valve motors, which I must not as yet describe in detail, are more economical in fuel than are even the Pegasus types and are actually the most powerful aero-motors in the world, although they are unfortunately still a good way away from the 4,000 horsepower units which are

—*Courtesy Aero Digest*



Bristol type 138 Monoplane.

wanted for the development of long range flying.

A Bristol monoplane, especially built for the job, recently beat the world's altitude record with the help of a Bristol Pegasus motor. So, judging by the regular swing of the pendulum, we hope before long to be able to capture the long-range non-stop record and the speed record as well.

The third phase of British aeronautical engineering is a particularly interesting development. To build up our Air Force as quickly as possible and at the same time to have a reserve capacity for turning out aeroplanes and motors in time of war, the Air Ministry has decreed that what is officially called a "Shadow Industry" shall be built up behind what the Air Ministry calls the Professional Aircraft Industry. Six of the biggest motor-car firms have been pressed, or rather persuaded, into the Government's service. Each company is charged with the job of building a factory and equipping it with modern machinery. Workmen are to be found from somewhere, and are to be trained in the use of that machinery, and each factory is to be run by the technical staff of the motor-car firm with which it is connected.

These "shadow" factories are to reproduce motors and aeroplanes to the designs of the professional aircraft firms.

In itself, the idea is good. But unfortunately the Air Ministry has decreed that instead of each factory making a complete motor and staking its own reputation on the quality of its output, one factory is to make crankshafts, another is to make crankcases, another is to make cylinders, another is to make valve-gear and so forth, and the whole lot are to be assembled in one central assembly factory.

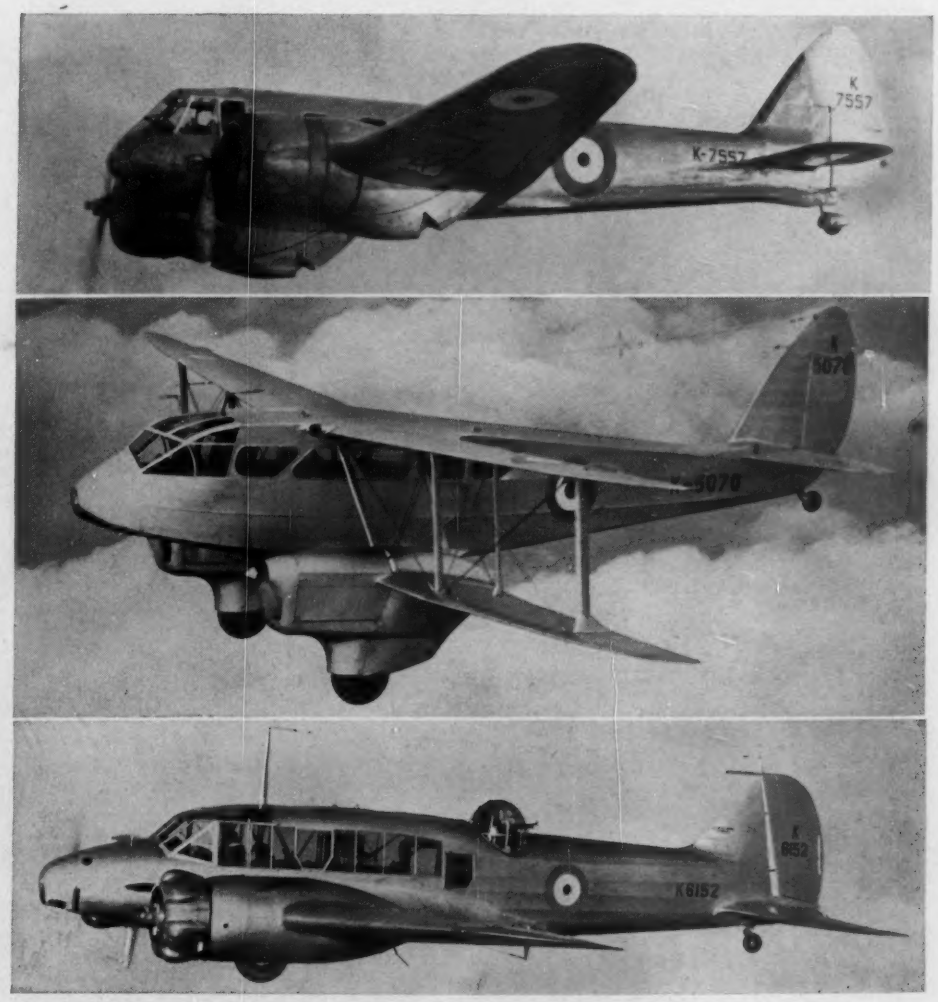
Obviously the scheme is wrong, because if one factory is bombed or if the men go on strike or if the power plant breaks down, the output of that factory will stop and the output of all the other factories will be held up. The probability is that by the time these notes appear in print the whole scheme will have been revised on a more sensible basis. By the time the people who are to operate these shadow factories have had a year or two of experience in the works, they will have become so bitten with the aviation "bug" that they will want to continue making aeroplanes and aero-motors, although the Government plans that the factories shall be shut down and the equipment shall merely be held as a war reserve as soon as the Air Force has been expanded to its limit.

What will probably happen is that by the time the Air Force has been expanded there will be such a demand for civil air transport machines that all the people who have been trained in the shadow factories will find plenty to do, either in the professional aircraft factories, or in the employ of new aircraft factories which will in due course be organized to build transport machines.

—Photo courtesy Imperial Airways

Berth arrangement in the new Empire Flying-Boats for Imperial airways.

—Courtesy Aviation



Top—Bristol 142.
Center—De Havilland D.H. 89.
Bottom—Avro Anson.

WING CONSTRUCTION

Who's Who Among

AIRCRAFT MANUFACTURERS

In the United States

By S. PAUL JOHNSTON, '21
***Editor of* Aviation**

PITTSBURGH for steel, Detroit for automobiles, but, so far, ——— (?) for aircraft. At one time Wichita was "it." In fact, air travellers landing on the municipal airport are still informed by a large sign that it is "The Air Capital of the U. S." But the letters are becoming somewhat dim with age and production isn't what it used to be, although several of her factories which have been manned only by watchmen in recent years are beginning to show renewed signs of life.

Los Angeles and San Diego (although we shall probably be in the dog house with both their Chambers of Commerce for mentioning them in the same breath) are making strong bids for Wichita's former title. Within the past year or so several important units of the industry have packed their covered wagons and have whipped up the oxen for the long trek westward across the prairies. Verily, the influence of Horace Greely is not yet dead.

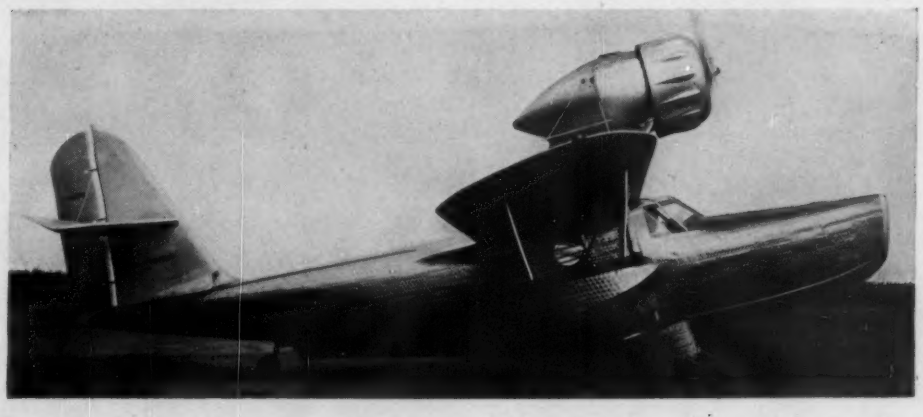
Whether or not the beauties—and we don't mean Hollywood Blondes exclusively—of Southern California will induce all the air-craft people to turn their backs on the East still remains to be seen. Although at the moment, a large share of the country's aviation budget, both commercial and military, is being spent on the Pacific Coast, enough of it is going to other sections of the country to warrant the statement that the aircraft industry is still pretty well scattered over the face of the land. Hartford is still, and will undoubtedly remain an important center. Baltimore is to be reckoned with—the New York area is not to be sneezed at—and even such obscure little towns as Bradford and Bristol, Pennsylvania or Alliance, Ohio, are beginning to make their voices heard.

If all manufacturers confined themselves to the production of military aircraft *exclusively* or commercial aircraft *exclusively*, the industry would be much easier to classify than it is. Such is far from the case, however, for we find concerns running the whole gamut of types from outfits like Consolidated and Chance-Vought operating on a wholly military basis, to Douglas and Boeing with concurrent orders for commercial and military planes, to Waco or Stinson with a predominantly commercial product with occasional military operations to Aeronca and Taylor predominantly commercial (unless primary training on light planes be considered as military matters). It is difficult, then, to break down our aircraft manufacture into simple categories. Next best is to have a look at the several units of the industry individually, grouping them geographically, starting on the West Coast and moving outward.

On the Pacific, the most spectacular industry development of recent years has been the rise of Douglas Aircraft from a relatively small military contractor to the largest manufacturer in the world, producer of transport equipment now standard for many airlines of the United States and abroad. The Santa Monica factory has doubled and redoubled in size. Its output, which once was confined to army observation and general purpose types, now includes practically everything from open cockpit land planes to huge multi-engined flying boats. Just completed is an order for seventy-one observation ships for the Army. Since May 1934, close to 150 DC-2's have been delivered, for the airlines, and for Army and Navy transport. A large two-engined amphibion (for both Army and Navy) is under development, an outgrowth of the famous Dolphin (now extinct). An order for eighty-six huge bombers for the Air Corps is under way. Production lines are now rolling off DC-3's and DST's, and a corps of engineers and carpenters are busy on the make-up of DC-4—a forty-passenger transport, ordered jointly by five of the major airlines, for 1937 delivery. Douglas altogether is reported to have a back-log of orders close to $30,000,000, an all-time peace-time record. Herein lies the reason why the many departments of the huge plant are filled with an astounding collection of jigs, fixtures, and tools for the most efficient production of parts from the smallest fitting to complete fuselages and hulls. The engineering department alone covers some 47,000-odd square feet of floor space. Between 350 and 400 engineers are pushing slide rules and turning out drawings by the yard under the watchful eye of Chief Engineer Arthur S. Raymond, '21. Donald Douglas, '14, heads the whole show. It is his baby, now grown to a husky manhood from an infant post-war project. Number two man is shrewd Harry Wetzel who still manages to keep his finger on the thousand-and-one details of plant management, as he has done for these many years.

Seven miles away, at Inglewood, is another Douglas interest, the plant of the Northrop Corporation. Donald Douglas and Henry Wetzel serve on its board of directors. Its president is Jack Northrop, old-time designer long associated with the production of high speed air-craft. W. K. Jay, as vice president, handles the intricate details of plant management. Northrop airplanes have been characteristically of the single-engined, all-metal type. The Greeks had words for them.

—Courtesy Aero Digest



Stainless steel hull of the new Fleetwings amphibion.

—*Courtesy Aviation*

Air brakes.

Earliest models, *Alphas*, carried TWA's mails over the Alleghenys and the Rockies. The *Beta* was a small two-seater with open tandem cockpits that never went into production. *Deltas*, as transports, flew the airlines until regulations against the use of single-engined equipment eliminated them, but still are used as "yachts" for private runs. Frank Hawks made the first *Gamma* famous, a tradition that has been carried on by Jack Frye and Tommy Tomlinson in TWA's experimental *Gamma*, equipped especially for sub-stratosphere research. But military rather than commercial planes roll out of Northrop's back door today. Swift attack types for our own Air Corps and light bombers for export have been keeping the plant busy.

Across the road from Northrop, and just on the edge of Los Angeles' municipal airport is a brand new plant—modern in every respect—the home of North American Aviation's Manufacturing Division—one of the units that recently turned its back on the effete East for the benefits of California sunshine, and moved lock, stock, and barrel from the old B/J plant at Dundalk, Maryland. It is now engaged in turning out planes of the general purpose types for the Air Corps and for export. One basic type is in production: a single-engined, low-wing monoplane with covered cockpits. By offering a selection of engines, optional retracting undercarriage, and by making arrangements for a wide variety of equipment and armament, the ship covers an astonishing range of performance and usage. J. H. (Dutch) Kindelberger, an old Douglas man, is in charge.

Not long ago at Glendale, but lately removed to the old Emmsco plant at Downey is another California concern which, like Northrop, has been specializing in single-engined, low-wing, all-metal aircraft. The Airplane Development Corporation is a Cord-owned unit, headed by Don P. Smith, with Gerald F. Vultee as Chief Engineer. Vultee transports were, until recently, in use on American Airlines' run from Ft. Worth to Chicago, but have since been retired in favor of twin-engined equipment. A development from the V-1 transport is the V-11 attack bomber, a military model recently released for export. Reports are current that Vultee is at work on a multi-engined ship, but so far no public showing has been made.

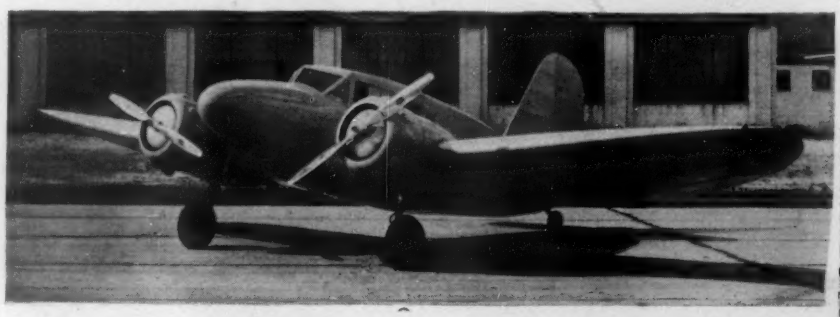
Lockheed of Burbank made history on several occasions by the performance of the early Air Express and the later Vegas. Several years since, however, the wood construction that typified these models was abandoned in favor of the more modern metal monocoque. Since 1934 the twin engined Electra transport, standard equipment on Northwest Airlines, Braniff, and other lines, has established itself as an efficient passenger and cargo carrier. Electra's little sister, more prosaically designated as the Model 12, has recently made a bid for the feeder line and executive transport market. A larger version of Electra—for fourteen passengers—is in the engineering stage, but so far has not been seen. Certain military models are also said to be in design stages.

Kinner, located just off Glendale's Grand Central Airport, is not as active in the airplane field as it was several years ago, although a number of single-engined sport types, both open and closed, have been delivered during the current year. A twin-engined type, the Envoy, designed to the Department of Commerce feeder-service specifications, has also been turned out. Major attention at Kinner appears to be in its engine department. Its five-cylinder radials have been widely used, and more recently entry has been made into the high-horsepower field with a seven-cylinder model for civilian use, and a fourteen-cylinder, twin-row type for the Navy, exhibited for the first time—under close guard—at last year's show in Los Angeles.

Besides these larger units the Los Angeles area is the home of a number of smaller producers—catering mostly to the private owner or small transport market. Aeroneer is one of the latest, an all-metal, low-wing job by Aero Engineering Corporation of Long Beach. Air Transport Equipment Corporation (Glendale) offers several models, from the two-place, Kinner-powered P-2 plane, to a couple of twin-engined, six-place jobs for floats or wheel mounting. . . . The Timm Brothers, Otto and Wally, in their shop at Grand Central, are designing a twin-engined ship of their own, and are building five twin Menasco-powered ships under contract for the Crusader Aircraft Corporation of Denver. Larry Brown (The Lawrence W. Brown Aircraft Corporation) specializes in fast ships, has built two outstanding Menasco-powered race jobs in his shop in the last few years. The McGaffey Airplane Development Corporation (Inglewood) has an unusual-looking experimental ship, the *Aviate*, powered with a converted Ford engine. Out at Van Nuys airport Security National is turning out single-engined, low-winged, open-cockpit Sportsters for land or water. Waldo Waterman, designer of the tailless ship delivered to the Bureau of Air Commerce last year, is rumored to be at work around Santa Monica on a new tailless type which is made roadable by the removal of its wings.

Some one hundred and fifty miles to the south is another center of California aviation activity—the city of San Diego. Here Consolidated settled last year when President Reuben Fleet decided that the Buffalo district had become too cold for him. Here he has built one of the most magnificent aircraft factories in the world with acres of well-lighted floor space under its saw-tooth roofs. The location is a happy one, for ships for the Navy may be delivered directly from the production line to the North Island Base, just across the harbor. The climate, too, is well suited to year-round flying. The original

—*Courtesy Aviation*



Lambert Monocoach.

—*Courtesy Aviation*

Interior View of modern airliner under construction.

plant, less than a year old, is now being doubled in size to accommodate orders now on the books and in prospect. A lot of fifty of the PB-2A attack ships for the Air Corps (a low-wing monoplane with retractable landing gear, powered with the liquid-cooled, geared Wright Conqueror engine) has just been completed. In process of construction now is a series of sixty twin-engined flying boats of the PY3 type for the Naval long range patrol duty. The Bell Aircraft Corporation, now operating in the old Consolidated plant in Buffalo, is building the wing panels for these boats under a subcontract. The prototype set a world's long distance record when Commander Knefler McGinnes flew it from Norfolk, Va., via Coco Solo, C. Z., to San Francisco last year.

Hard by Consolidated's plant is Claude Ryan's factory (Ryan Aeronautical Company), specializing on a tandem two-seater with open cockpits of the sport type. This low-wing monoplane has a metal monocoque fuselage, fabric-covered wooden wings, and is powered by Menasco. Last year some fifteen of these ships were sold. By the end of the first ten months of 1936 that number had been more than doubled.

Before leaving the West Coast we must take a long jump to the north to look in on Boeing at Seattle. One of the oldest aircraft manufacturers in the United States, Boeing has been doing business at the same stand since 1916. Over 1,900 airplanes of all types have been turned out in that twenty-year period. Although production has been predominantly military, Boeing has turned out a line of commercial craft with long and honorable careers. Boeing 40's and 95's made air-mail history. The 80's and 80A's—huge three-engined biplanes, flew the transcontinental airways of United until replaced in 1933–34 by the well known 247's, prototypes of all modern two-engined, low-wing, all-metal transports. Modernized by engine replacements and by a number of internal and external changes (now the 247-D's) these ships are still doing yeoman service, flying better than 40,000 miles a day from coast to coast, from Canada to Mexico.

Boeing is now busy on an order for thirteen four-engined bombers for the Air Corps (the 299). Initial engineering construction work has started on an order for six 82,000-pound flying boats for the transoceanic commercial services of Pan American.

San Francisco has never been much of a spot for aircraft production, but reports are current that Lloyd Stearman and Dean Hammond have negotiated for a factory there where they may turn out Commercial versions of the Hammond Y pusher developed last year to meet the Department of Commerce light plane specifications.

Except for Wichita there is no city between the Rockies and the Alleghenies toward which aircraft manufacturers have tended to gravitate in numbers. Wichita still has three important units of the industry—Beech Aircraft, Stearman Aircraft, and Cessna. Walter Beech is specializing in high-speed ships for the private owner. His sleek-looking Beechcraft biplanes with their characteristic negative stagger and retracting landing gears are good for from 180 to better than 200 miles per hour, depending on their power. A twin-engined, low-wing, all-metal transport for six or eight people is under development.

Stearman is associated with Boeing. It has done much contracting on parts for Boeing transports and also turns out several models of open cockpit biplanes, single-engined, for military training and for general sports purposes.

Cessna has long been settled in Wichita. Very active in the late twenties, Clyde Cessna used the depression years as a chance to revise his design, and lately has gone into production on the Model C-34, a Warner-powered monoplane for four that took the ATC contest for general efficiency at the 1935 Air Races.

Spartan, at Tulsa, Okla., has been showing lately a new all-metal, low-wing job, the "Executive," which is intended for fast business travel, and for the private owner who wants speed and performance.

Further east, Kansas City is the home of Porterfield, Rearwin, and American Eagle. These concerns offer aircraft for the private owner. The former has just announced a new machine, the Zephyr, which is to sell at $1,295, approaching the $700 airplane idea. Rearwin's planes are in the lightweight class, available for five-cylinder-radial or four-cylinder-in-line engines.

American Eagle's "Eaglet" is one of the few light planes that survived throughout the depression. It is a parasol monoplane with Szekely engine, for two people.

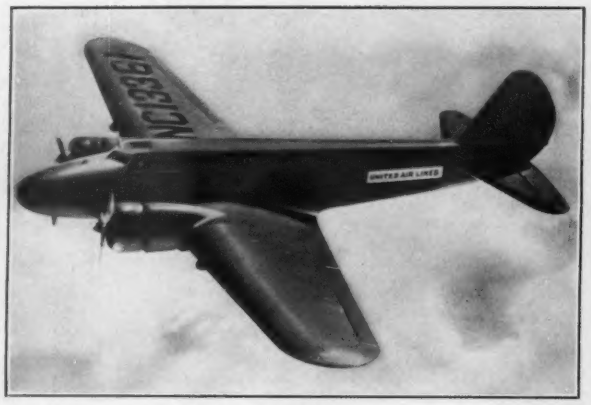
(*Continued on page 179*)

—*Courtesy Aviation*

Sikorsky S-43 for export.

Lockheed Electra

Boston-Maine Airways . . . . . *Boston-Bangor*
Braniff Airways . . . . . *Chicago-Brownsville*
Central Vermont Airways . . *Boston-Burlington*
Chicago & Southern Air Lines *Chicago-New Orleans*
Delta Air Lines . . . . . *Atlanta-Dallas*
Eastern Air Lines . . . . { *Chicago-Miami* / *Atlanta-New Orleans*
Hanford Airlines . . . . . *St. Paul-Tulsa*
Northwest Airlines . . . . . *Chicago-Seattle*

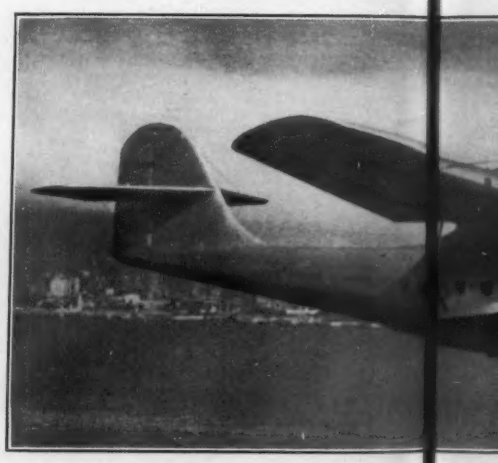


Boeing 247-D

United Air Lines . . . . . *Trunk Lines*
National Park Airways . *Salt Lake City-Great Falls*
Pennsylvania-Central Airlines . . . . . *Washington-Milwaukee*
Western Air Express . . *San Diego-Salt Lake City*
Wyoming Air Service . . *Pueblo-Denver-Billings*

Dou DC-

American Airlines . . .
Eastern Air Lines . . .
Pan American Airways .
Transcontinental & Western .
United Air Lines . . .
Western Air Express . . .



Martin Clipper

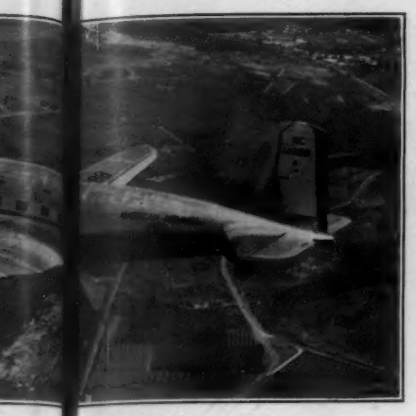
Pan American Airways . . . . . .

ACHIEVED BY DAUNTLESS RESOLUTION AND UNCONQUERABLE FAITH

IN THE PAST 24 HOURS 10% MORE PASEN
WERE FLOWN THAN IN TE

This unprecedented advance has been de
of the airlines with egine

** Official Department of Commerce figures for airlines of the United S how that*
miles were flown in 1926, and at the present time a daily average o 00 pound

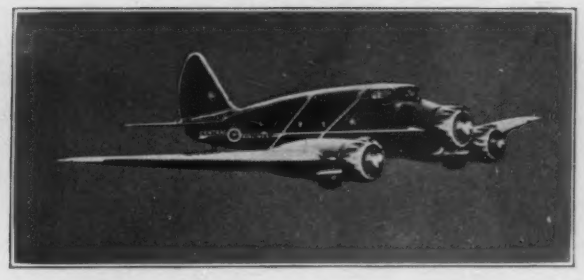


Dou DC-3

. . . . .	*Trunk Lines*
. . . . .	*On Order*
. . . . .	*On Order*
estern	*On Order*
. . . . .	*On Order*
. . . . .	*On Order*

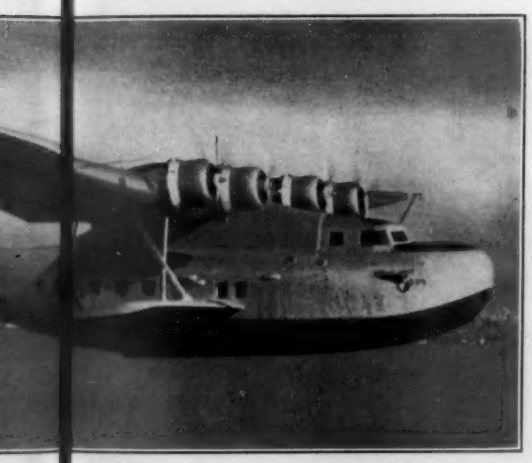
Douglas DC-2

Transcontinental & Western Air . .	*Trunk Lines*
American Airlines	*Trunk Lines*
Eastern Air Lines	*Trunk Lines*
Pan American Airways	*Land Routes*



Stinson-A

American Airlines	*Feeder Lines*
Pennsylvania-Central Airlines	*Washington-Detroit*
Delta Air Lines	*Atlanta-Charleston*



Iarti pper-130

. . . . . *San Francisco-Manila*

ASENGER MILES AND 400% MORE EXPRESS
TE ENTIRE YEAR OF 1926*

n de possible by the constant co-operation
h egineers and designers.

nited S ow that 3,555 pounds of express and approximately 1,290,000 passenger-
erage o 00 pounds of express and 1,400,000 passenger miles are being flown.

ME TIGHTLY BOUND

Innovations In

AIRCRAFT INSTRUMENTS

Assist Blind Flying

By PROFESSOR CHARLES S. DRAPER, '26
Assistant Professor of Aeronautical Engineering

HUMAN senses are unable to supply accurate information on many quantities of vital importance in modern life. For example, long electromagnetic waves cannot be detected without the aid of a radio set, while an accurate estimate of automobile speed requires a speedometer. In even the simplest matters of existence, human beings have come to depend on devices which translate physical quantities into motion of a pointer along a scale. Always after it becomes possible to measure a quantity the next step is to develop apparatus for automatic control. Thus the thermometer contributes to comfort by giving an accurate knowledge of room temperatures and it is an obvious procedure to maintain a desirable condition by means of a thermostat. In many instances not only the comfort but even the safety of large populations depend upon the consistent operation of automatic control equipment. The effects of a complete failure in the voltage regulators of an electric power system could easily be very serious. So important are the functions of measurement and control that the growth of an industry must be accompanied by a parallel development of suitable instruments. Aviation is an outstanding example of an industry which has been made possible on a large scale by a great outlay of time and money on instrument problems.

Pioneers in the field of aircraft instruments have steadfastly worked toward the goal of making aircraft operation independent of weather conditions. This means that a pilot should be able to take-off, fly directly to any selected destination and land without the aid of visual references outside the cockpit. Today specially trained pilots flying specially equipped airplanes can take-off, fly and land blind with the co-operation of special ground apparatus, but much work remains to be done before such a procedure becomes safe routine in commercial operations. A pilot flying without instruments is entirely "blind" in a dense fog. He has no accurate information on the position or orientation of his airplane and can detect trouble in his power plant only after an actual failure has occurred. Such a situation will usually be ended by disaster after a short time. Before aviation could progress much beyond the stage of a fair weather sport, it was necessary to supply the pilot with mechanical and electrical "eyes" to give him control of his airplane and its course in any kind of weather. Instrument manufacturers have been so successful in the solution of this problem that extended periods of blind flying are now considered trivial incidents in the course of a pilot's normal duties. This result has been accomplished largely within the last decade, although blind flying instruments were developed to a usable state by the end of the World War. The "old time" pilots of 1920 to 1925 "got on the ground" at the nearest field in the event of thick weather and this mental attitude was carefully instilled into young pilots. With the equipment available at that time this was the wisest course, although this same equipment was used for many hours of blind flying after the Air Mail had introduced the necessity for such operations. The first stages of the blind flight era consisted in the growth of satisfactory methods for use of the instruments already available. As the art developed the need for more convenient and more accurate instruments was quickly followed by new equipment. Major James H. Doolittle, working under a grant from The Daniel Guggenheim Fund for the Promotion of Aeronautics, pioneered blind flying and in particular was able to carry out successful blind landings. The books by Howard Stark and

—*Courtesy Pioneer Instrument Co.*

Fig. 1 Preview of New Pioneer Sensitive Altimeter.
This newly designed Sensitive Altimeter will indicate altitude of a plane within five feet from sea level to 40,000 feet.

—*Courtesy Sperry Co.*

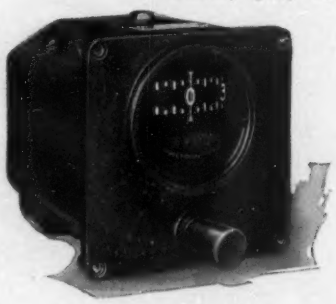


Fig. 2.—Sperry directional gyro.

—*Courtesy Sperry Co.*

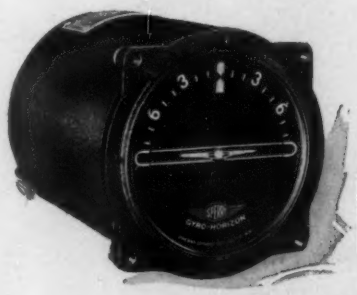


Fig. 3.—Sperry artificial horizon.

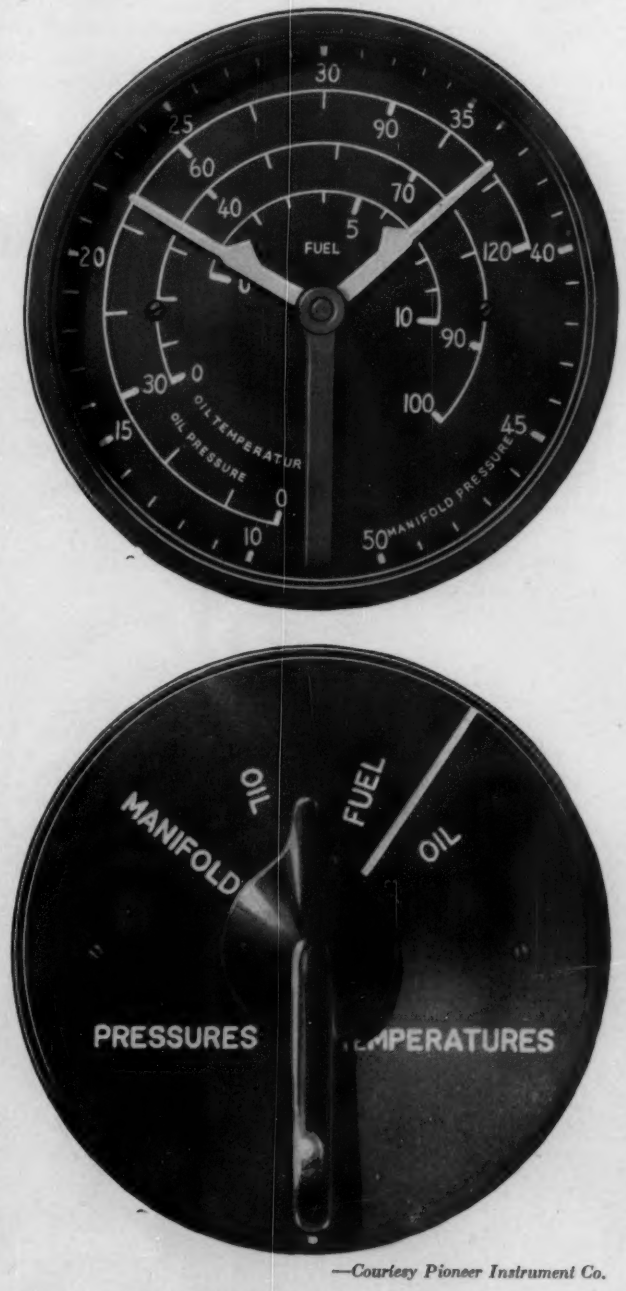
Major W. C. Ocker and Captain C. J. Crane of the Army Air Corps made the new technique available to other pilots and served as texts for training purposes. Instrument developments were largely carried out by the Sperry Gyroscope Company, the Pioneer Instrument Company and the Kollsman Instrument Company. These three concerns still carry on a major portion of the business in aircraft instruments.

In flight, the pilot is concerned with many things; he must have accurate information on conditions in his power plant; he must know the attitude, the speed, and altitude of his airplane; in addition, he must be sure of his position and direction. Power plant instruments include a tachometer for indicating engine speed, gages for oil, manifold and fuel pressures, remote reading thermometers for important temperatures, and fuel supply meters. A second group of instruments, called the flight instruments, is composed of the indicators necessary to maintain safe flying conditions. Flight instruments include the altimeter, the airspeed meter, the rate of climb meter, the magnetic compass, the gyroscopic turn indicator, the Directional Gyro, the Artificial Horizon, and the bank indicator. The various means for locating the airplane and checking its course over the earth's surface such as the radio, drift sights, and celestial navigation devices are known as navigation instruments. In addition to these groups, another set of indicators is associated with the airplane itself to show such things as control and landing gear positions. Finally there is always a more or less extended equipment of special instruments which depends upon the type of service in which an airplane is to be used. The illustration on page 182 gives an idea of the complicated array of dials and controls which confronts the pilot of a modern transport.

The almost superhuman task of a pilot is apparent when we consider that he must not only know how to read all these instruments but must be able to skillfully interpret all the readings under circumstances in which even a small mistake can have fatal consequences. It is not surprising that the trend is toward complete automatic control of the airplane and its power plant even at a considerable cost in weight and mechanical complication. The most widely used system for automatic control of aircraft has been developed by the Sperry Gyroscope Company using the gyroscopic units of their indicating instruments as the basic elements. Delicate relays operating the valves of oil cylinders are used to transfer displacements with respect to the gyros into proper motions of the airplane controls. Mechanical pilots are so useful that it is now usual practice to include such a device in the equipment of large airplanes. Human pilots still have to handle the controls during take-off and landing but in flight all the routine operations are performed automatically except for an occasional check of position and course. The external appearance of the control unit for a gyro pilot is shown at the center of figure 5.

The difficulty of transferring pressure and mechanical indications over the considerable distances necessary in large airplanes has started the use of remote indicating systems. That is, the dials in front of the pilot become merely repeaters which show the position of the indicating element in working units located away from the instrument board. Such a system permits the use of several indicators operated from the same sensitive unit to give simultaneous readings to the pilots' compartment, the navigator's compartment, the engineer's compartment, etc. By the use of repeaters it is also possible to combine several indications on the same dial and thus somewhat reduce the strain on a pilot who must continually keep in mind a large number of separate indications.

Figure 4 shows the face of a unit for indicating several quantities on the same dial. This unit is operated electrically by small self-synchronous motors developed by the Pioneer Instrument Company and called "Autosyns." These motors operate in pairs, one motor being mounted on a mechanism sensitive to the quantity to be measured while the other motor controls the pointer position on the indicating unit. By means of the selector switch shown, the same dial can be used for several different quantities by connecting the receiving motors to various control motors. The Autosyn system is finding many applications especially in large airplanes.



—Courtesy Pioneer Instrument Co.

Fig. 4.—Multiple indicating dial and selector switch of "Auto Syn," Electrical Indicating System.

One of the instrument problems which has been solved to a surprising degree of perfection is the indication of altitude by means of atmospheric pressure. The so-called sensitive altimeters which are standard equipment on airplanes for blind flying can detect changes in height of five feet with a maximum range of forty thousand feet. This type of instrument was first manufactured on a commercial scale by the Kollsman Instrument Company and formed the basis for the company's success. The appearance of a sensitive altimeter manufactured by the Pioneer Instrument Company is shown in figure 1. One revolution of the long hand corresponds to one thousand feet altitude, the next smaller hand makes one revolution for ten thousand feet and the smallest hand makes one turn for forty thousand feet. Near sea level a pressure change of one millimeter of mercury corresponds to about thirty-seven feet in altitude. Since the ordinary fluctuations of barometric pressure have a range of

(*Continued on page 181*)

Engineers Seek In

PROPELLER DESIGN

Greater Motor Efficiency

By FRANK W. CALDWELL, '12
Engineering Manager, Hamilton Standard Propellor Co.

THE propeller may be considered a connecting link between the power plant and the airplane, and its design is intimately related to both.

A propulsor of some kind is necessary in all proposed schemes of air transportion except the helicopter, where propulsion comes from tilting the axis, though which the main supporting surfaces become, in effect, propellers, and the ornithopter where propulsion is obtained by flapping wings.

At the moment, the screw-propeller is the only accepted form and it appears likely to remain so for some time. And with good reason, because in comparison with other devices, it is highly efficient, light and cheap, and occupies very little space in proportion to the volume of air which it sets in motion.

The primary function of the propeller is to provide a traction or propulsion to the aircraft in the direction of motion, and it can only do this by setting in motion a certain mass of air in a direction opposite to the motion of the aircraft. The best propeller is the one which provides a given amount of traction while setting in motion the largest possible mass of air at the minimum velocity and with the least possible losses due to eddies, whirls, and pressure waves of one kind or another. Our aerodynamic investigations are directed mainly at the study of these losses.

Like most branches of aerodynamics, a great part of the technical knowledge of propeller aerodynamics has been obtained by making tests of models in the wind channel. These tests are of two distinct types: those made with geometric models having a scale ranging from one fourth to full size, and those made with small wing sections having a profile similar to that of the propeller. In the latter type of experimentation, the results are applied to the complete propeller by means of a series of mathematical calculations.

Suitable mathematical formulae have been developed for transferring the model results to full scale, but considerable care has to be exercised in their use because the results are influenced by viscosity effects at low speed and by compressibility effects at high speed.

For the airplane designer who is primarily interested in the effect of the propeller characteristics on the performance of his aircraft, the tests of the geometrical models are of primary importance.

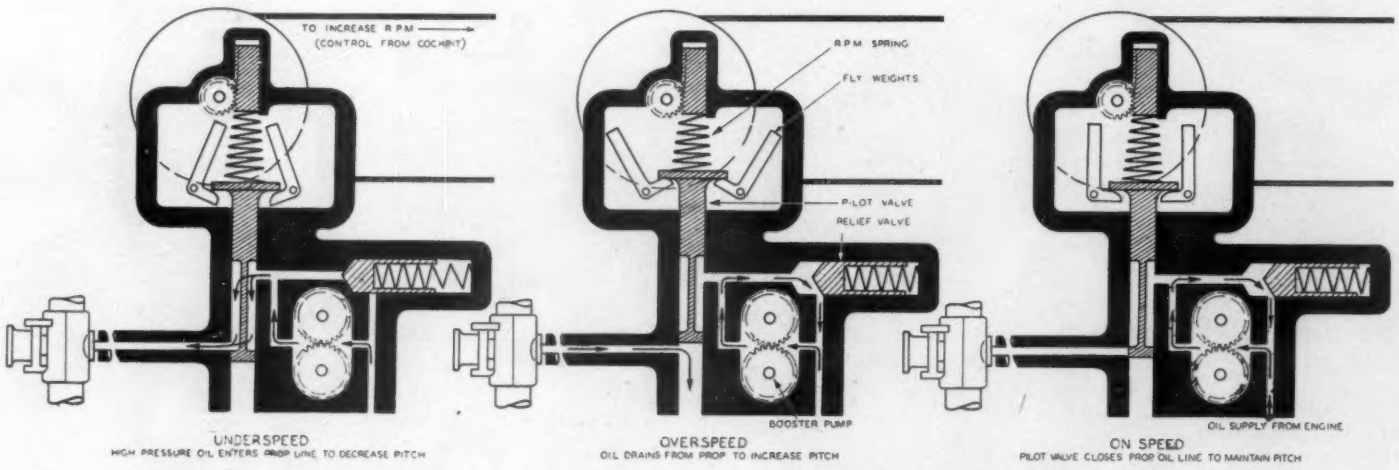
For the propeller designer, however, the airfoil test with its associated mathematical analysis is, perhaps, of greater value since it permits a study of wide departures from existing design practice and lends itself to analysis of existing designs with a view to improvements.

The compressibility effects on the propeller characteristics become of great importance as the velocity of sound is approached, and there is a striking loss in efficiency as the speed goes up. We have found, however, that we can use higher speeds efficiently if the sections are kept very thin, and this fact has been an important influence in leading to the almost universal adoption of solid metal blades which permit the designer to reduce the thickness of the sections.

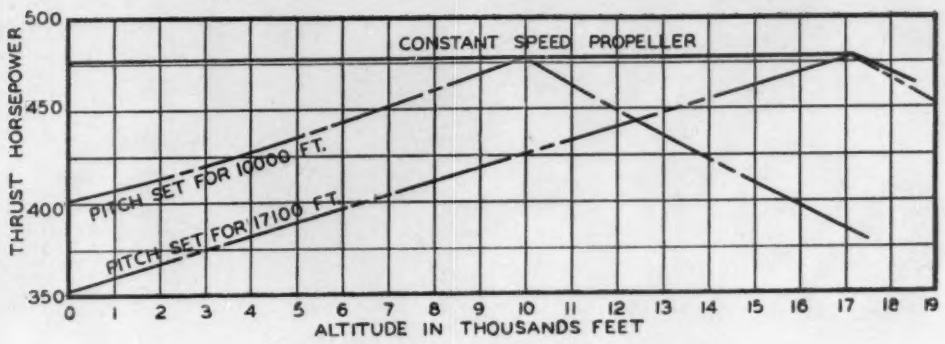
The propeller characteristics are such that we have had a progressive improvement in propeller efficiency in level flight due to the increase in speed of the airplanes, since this increase leads to higher angles of helical advance for the propeller sections.

The propeller characteristics are just as closely related to the power plant, however, as they are to the airplane. For a long time we were able to connect the propeller directly to the engine crankshaft with fairly good efficiency. As the size of the engines has increased, the crankshaft speed has been raised at the same time so that we have finally had to resort to the use of gearing between the engine and propeller in order to keep the speed of the propeller well below the velocity of sound. This lower propeller speed has further increased the angle of helical advance so that the high speed airplanes and geared engines provide conditions which are nearly ideal from the standpoint of propeller efficiency in level flight. The helical

—Illustrations courtesy Aero Digest



Diagrams illustrating the operation of the Hamilton constant speed propeller unit.


CONSTANT SPEED PROPELLER
PITCH SET FOR 10000 FT.
PITCH SET FOR 17100 FT.
THRUST HORSEPOWER
500
450
400
350
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
ALTITUDE IN THOUSANDS FEET

Thrust horsepower in level flight with different types of propellors.

angles have become so high, however, that the propellers were working very inefficiently at the takeoff due to a condition similar to the stalling of the airplane wing, which occurs at high angles.

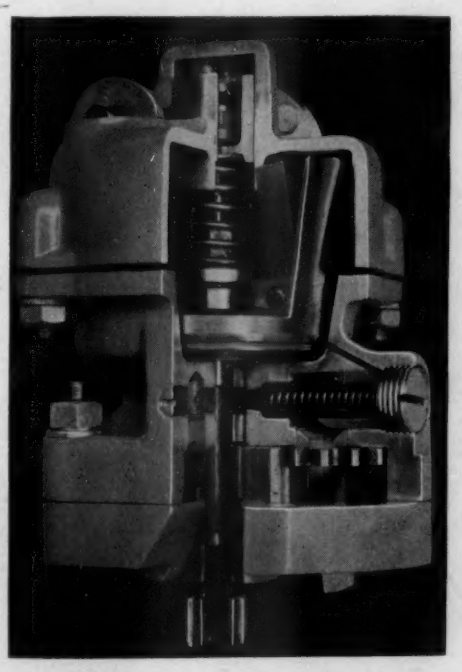
The only effective remedy for this difficulty lies in the use of one set of propeller blade angles for takeoff and a second set for level flight.

Another engine development which has had an important affect on the propeller is the use of superchargers and other devices which permit the engine to develop the same horsepower from sea level up to altitudes of 15,000 to 20,000 feet. If we design a suitable propeller to absorb the power of the engine at the proper rate of rotation in the rarified air at 20,000 feet, the propeller characteristics are such that the engine would only turn at about sixty per cent of the rated power at takeoff and the engine power available would be reduced to about sixty per cent of the normal.

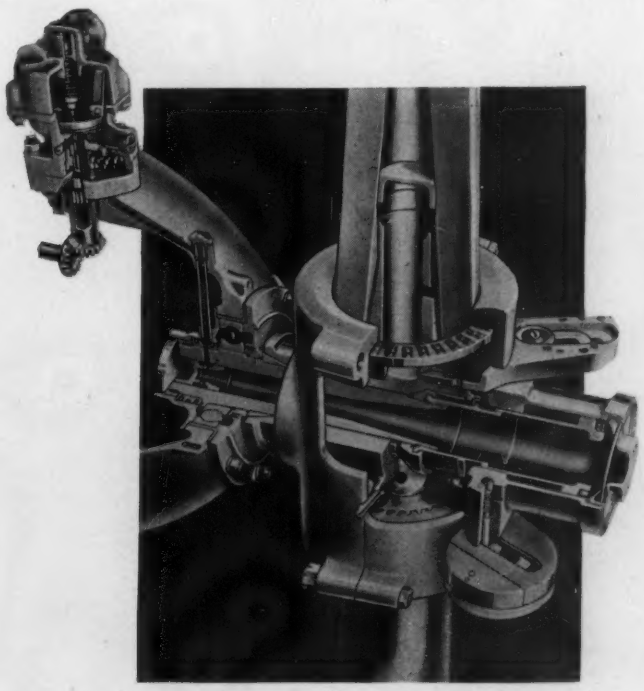
In modern airplanes, the takeoff is just the time when the greatest power and good propeller efficiency are most important so that it became indispensible to have a controllable pitch propeller so that we could change the blade angles in flight and permit the engine to develop full power at takeoff with good propeller efficiency and still permit suitable conditions for level flight by adjustment of the pitch angles.

Fortunately, our research during the past twenty years together with our familiarity with the solid metal blades, had given a good background for the design of this device and we were able to make it available to the airplane designers and users with a minimum of inconvenience.

There are, of course, many features relating to the structural and mechanical design of the propeller and it is these features which require the greatest effort. No doubt further radical improvements will be needed as we use power units of much greater horsepower and fly at still higher altitudes.



Cutaway view of the governor unit for the constant propellor.



Cutaway view of propellor hub.

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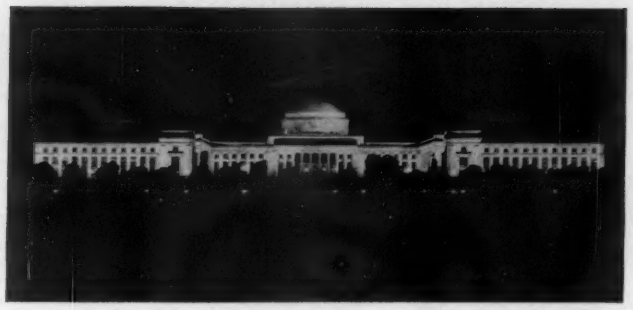


EDITORIALS

TREND IN AVIATION

THE past year has been an unusually productive period for engineering and technical advancements in the aeronautical field. Development of new manufacturing materials and the practical application of many new devices and accessories have added to the safety and economy of air travel. Larger airplanes are being produced for the airlines and equipment is becoming more standardized to facilitate replacement of parts and affecting the saving in cost attending increased production.

Among the interesting types of airplanes making their appearance toward the end of the year are the Douglas DC-3 which combines the latest technical developments with many innovations for passenger comfort, and the Fleetwings "Sea Bird" amphibion which utilizes shot-welded stainless steel in its structure. Research in the field of acoustics has been responsible for the design of cabins in which the noise level has been lowered to a marked degree. Heating and ventilation problems have also been dealt with successfully in the modern transport which will be larger, faster, and more comfortable for flight by day or night. Sleeping berths, larger and more comfortable than before, are provided on several of the airliners and adequate buffet equipment with ideal facilities, make it possible to serve more extensive and diversified meals aloft.

Engines developing 1000 to 1200 horsepower are being installed in new military planes as well as the transports. Research and development continues on Diesel engines for aircraft and on larger horsepower in-line, Vee, and H-types for military utilization. For transocean airlines, larger flying boats are being constructed, based on the operating knowledge gained from Pan American Airways' successful operations across the Pacific. The use of constant speed propellers is having a wide acceptance in every branch of flying—private, commercial, and military.

The installation of de-icer equipment and means for preventing ice formations in carburetors and on propellers has reduced or eliminated the hazard of flight in atmosphere conducive to icing conditions. Radio aids have aided materially in the safe maintenance of schedules in adverse weather.

During the year, the United States retained its lead in the race for official world records, indicating that we still are far ahead in aero-dynamical achievement. Forty-six world records are held by American pilots, compared with 34 by Frenchmen, our closest competitors.

George F. McLaughlin,
Editor AERO DIGEST

AERONAUTICS AS A FIELD OF ENGINEERING

AERONAUTICAL Engineering, although closely related through common fundamentals to several other divisions of engineering is unique in many ways. Historically it had a very singular beginning. The necessities of the World War forced the various governments to develop aviation—then in its infancy—very suddenly and effectively into a major field of engineering. This development not only resulted in a simultaneous and coherent advance all over the world of all branches of the field, namely: design, production, transportation, landing fields, schools and laboratories, in a manner quite unprecendented in the history of any engineering field, but it resulted also in placing the future of aeronautical engineering in the hands of large groups of war-trained men whose outlook and training, regardless of nationality, was remarkably uniform and whose ages fell within a surprisingly narrow band. Aeronautical engineering is equally singular in the way it subsequently developed. To meet demand, it often found it necessary to increase the size and performance of its products, the airplane and the airship, at a higher rate and in larger increments than is usually accepted as advisable in other fields of engineering. These large and frequent steps ahead have placed an unusual strain upon the aeronautical engineer, upon the aerodynamic laboratories, and upon the ingenuity of the industry.

From the standpoint of the student, aeronautical engineering differs from most other fields of engineering in requiring an advanced grade of mathematics and mechanics as its foundation. A dynamic analysis made by an aeronautical engineer unfortunately does not start with a simple field marker or a concrete foundation, but with a free body having six degrees of freedom, the dynamics of which are quite complicated. Similarly, the airflow about the body is not as simple to express as the flow of electricity, but follows as many as three separate regimes, each with its own laws. To make matters worse, aircraft are driven by a pulsating kind of power whose magnitude compared to the mass of the structure is very large, at least according to the usual engineering conceptions, and which, therefore, introduces new problems in vibration. Adding still further to these difficulties, the demand for maximum lightness requires high-performance, light metals and refined engineering in analyzing stresses and in manufacturing the final aircraft. Thus aeronautical engineering as a profession is one of the most exacting of the whole engineering group. In the face of this, aeronautics is by far the most alluring of the engineering fields. The reason for this lure is not easy to explain, especially since it has always been disproportionately large compared to the pay and pay security which the field could offer and to the number of men it could absorb. To correct this situation as far as possible, enrollment in the aeronautical engineering course at the Institute has had to be restricted to a limited number of men each year, a restriction which is not required in any other field.

Aviation is also quite unorthodox as an industry. It is significant, especially from the standpoint of national defense, that this field has reversed a long-established rule with respect to the organization of an industry. Ordinarily, an industry supplies a nationwide market but is itself more or less centralized in a local region which is favorable to production. In aeronautics, the main market tends to be centralized, while the industry is decidedly decentralized, being spread, with remarkable uniformity, all over the country. Notwithstanding this wide decentralization, however, the aeronautic industry is far more uniform in its plant equipment, industrial methods, and production costs than is the case with most of our centralized industries in other fields.

Finally, aeronautics is quite unique among the engineering fields with respect to its relation to the Government. The National Advisory Committee for Aeronautics renders many services which no national society however strong could render. It maintains, for example, its own large aeronautical laboratories at Langley Field, Virginia; it publishes reports for public use covering not only the work done there but also the work of many other non-government contributors; and it supports a long list of research projects in the various educational institutions throughout the country which are properly equipped to carry on aeronautical research.

In view of the increasing importance of aeronautical engineering and the unusual rapidity of its growth, the Institute does well to plan for an enlarged aerodynamic laboratory as a part of its general expansion program. Our present laboratory has, in the natural advance of the art, come to need modernization. The new laboratory which has been proposed will, when constructed, again make it possible for M.I.T. to be fully effective in contributing to both the engineering and the scientific sides of this field.

RICHARD H. SMITH,
Professor of Aeronautical Engineering

AIR FREIGHT

FORESHADOWING a new enterprise in the air transportation industry, one of the major airlines of this country has recently inaugurated nightly schedules between New York and Chicago with "flying express cars". The planes used are Ford Transports which were retired from passenger service some years ago.

The consideration by airline officials of express planes results from a steadily increasing air express traffic. At times in recent months, express loads have over-run their compartments in the passenger planes to such an extent as to necessitate the operation of extra planes for the passengers. Starting with 3,555 pounds in 1926, air express has increased in every successive year, and in 1935, 5,511,737 pounds were carried by scheduled air lines of the United States. Air express poundage of the current year is about 75% ahead of the corresponding period in 1935.

Operators will welcome the all express flights as an opportunity to obtain more service from the airliners which quickly become obsolete as passenger carriers because of the advent of more luxurious and slightly faster planes. The average useful life of an airliner is about three years, after which it is retired from service, generally being sold at a sacrifice. This replacement program is made necessary by the rapid advancement being made in the design of airliners.

The keen competition between the airlines makes it necessary that an operator have the most modern passenger planes available in order to keep up with the field. Depreciation is therefore a large item in an airline's budget. Utilization as express ships, if future traffic justifies, of planes which have prematurely become obsolete in passenger service would help the financial condition of the airlines, as well as give jobs to additional airline engineers and technicians.

ENGINEERING DIGEST

TIME FLIES

PICTURED above is the new speed ship that Frank Hawks has just finished building and with which he plans to break many records. In addition to supervising its construction, Hawks acted as co-designer and is now putting the plane to rigorous tests in flight. A unique retractable cockpit enclosure lies far behind the 1150 horsepower R-1830 BG Twin Wasp engine. An automatic gas mixture control and a Hamilton-Standard constant speed propeller complete the power unit. The plane is equipped with a Breeze exhaust gas analyzer and the new Sperry gyro-magnetic compass, a combination of the gyro and magnetic compasses. Besides his sponsors, a nationally prominent watch company, all aviation enthusiasts are eagerly waiting to see what Captain Hawks will do with this new 375 miles per hour speedster.

—*Aviation.*

FLYING BOAT

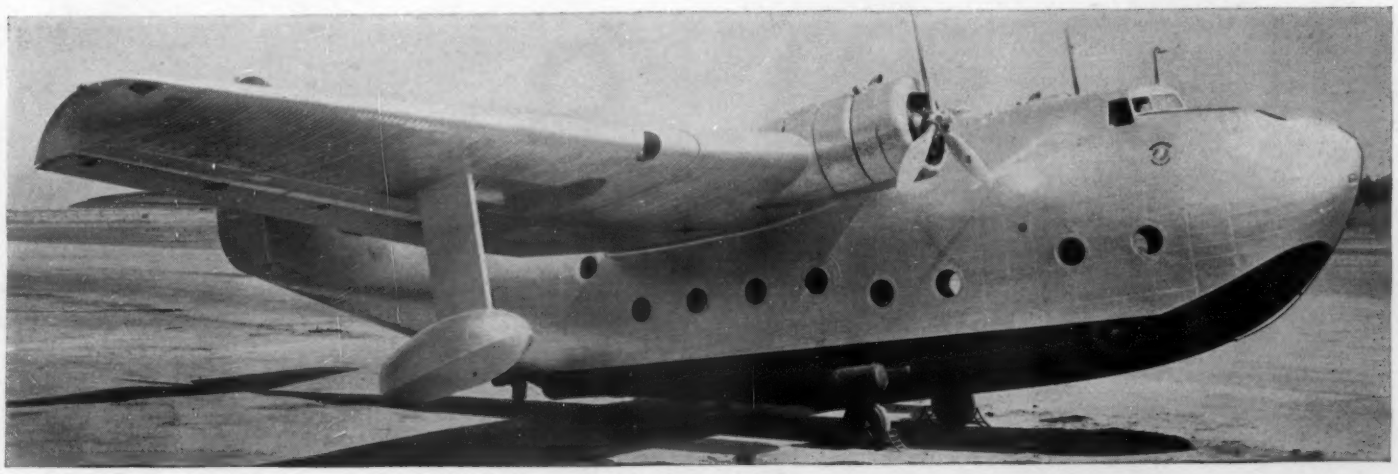
THE Douglas twin-engined Model DF flying boat is one of the finest and latest developments in airplanes designed for long range transoceanic service. The ship has an overall length of seventy feet and a wing span of ninety-five feet, providing accommodations for thirty-two passengers and a crew of four. The cabin, insulated against noise and outside temperature, is divided into four compartments, each with accommodations for eight passengers. Just aft the bow is the pilots' compartment, while behind the cabin and the two lavatories is a cargo compartment.

Except for the rudder, two piece elevators, ailerons, and hydraulically operated flaps, the ship is entirely covered with sheet metal. The wing is of all-metal full cantilever construction, incorporating the newest in design. Cantilever construction has been used also in the all-metal tail unit which has a span of thirty feet. The fin is sheet metal covered, while the rudder and two piece elevators are fabric covered. Elevators are statically and aerodynamically balanced and are equipped with trimming tabs. One novel feature of this flying boat is the retractable wing floats, one of which may be seen hanging from the wing at the right of the picture below. The floats are hydraulically retracted inward and partially recessed into the wing.

The ship weighs sixteen thousand pounds and is powered by two one thousand horsepower engines, equipped with three-bladed constant speed propellers. The airplane carries over sixteen hundred gallons of fuel, which gives it a non-stop, full load cruising range of fifteen hundred miles and a maximum range of thirty-three hundred miles with a twelve passenger load.

Judging by the records of similar airplanes, there is no reason why this new flying boat should not be most popular in providing better and more luxurious air transportation to the flying public.

—*Aero Digest.*



RESEARCH IN REVIEW

COURSE XVI — Aeronautical Engineering

VIBRATION problems in aircraft have attracted much attention in the past few years. The complex structures involved make it very difficult to gain satisfactory results by pure analysis. On this account, the most satisfactory procedure is to carry out measurements on the vibrating parts. Since no satisfactory apparatus was available, a co-operative project between the Bureau of Aeronautics of the United States Navy and the Massachusetts Institute of Technology was arranged to develop vibration equipment for aircraft work. This project was started in 1934 and has been under the general supervision of Professors Hunsaker and Taylor. Professor Draper has been in direct charge of the work which was carried out by G. P. Bentley, '34, and Russel Fanning, '30.

The apparatus consists of a specially constructed double element recording oscillograph, a vacuum tube amplifier and a variety of small vibration pickup units. Each pickup unit has a small electro-magnetic generator which gives an output proportional to the velocity of vibration. This output is applied to the amplifier which has a special circuit for electrical integration so that the amplifier output is proportional to the amplitude of vibration. The oscillograph uses motion picture film in lengths up to 100 feet and is designed for convenient operation in flight. All the apparatus can be operated from either a twelve volt storage battery or an ordinary lighting circuit. The equipment is now being used by Mr. Bentley to study vibration problems in a number of airplanes and engines.

In addition to the original vibration outfit, five sets of the equipment have been delivered under contract to various governmental and manufacturing agencies. The apparatus will be manufactured for general use by the Sperry Gyroscope Company under an agreement with Technology.

COURSE II — Mechanical Engineering

Development work on an electric cyclic pressure indicator has been carried out by C. E. Mann in the Automotive Engine Laboratory for the past two years. This indicator, now near the last stages of successful completion, is designed to give a trace on a cathode-ray screen of the pressure variation in an internal combustion engine cylinder over the combustion cycle. It permits remote inspection and recording of the indicator diagrams, and allows actual inspection of cycle-to-cycle variations and of changes in combustion phenomena as the engine conditions are altered. The construction of the indicator is small and compact and allows the viewing of conditions in an airplane engine in flight. The electrical pick up unit is comparatively rugged, varies only a very small amount with temperature because of its relatively heavy diaphragm, has no zero setting, and is not influenced by vibration, since the recorded output is the integral of the electrical input.

The means for supplying the electrical output varying with pressure is a small coil of wire which is deflected with the pressure diaphragm in a magnetic field. In accordance with simple electrical theory the output from the coil varies with the velocity of diaphragm movement or rate of pressure change within the engine cylinder. Originally this idea was suggested by Professor Trowbridge of Princeton, who tried to use it in sound detection. More recently a much more powerful instrument for the detection and measurement of detonation waves set up in an engine cylinder has been constructed at Technology.

A small unit of even greater sensitivity has been constructed by C. E. Mann. The unit is screwed down into an engine cylinder flush with the inner wall. The diaphragm and attached coil are displaced proportionally to the pressure variation within the cylinder. The electrical output, proportional to the time differential of the pressure, is carried by carefully shielded cable to a high gain amplifier capable of driving a cathode-ray tube. By sweeping the tube horizontally, either linearly with time or proportionally to piston motion, by means of a small mechanical system, time or volume records of combustion conditions can be obtained.

These records of rate of change of pressure are useful for determining time of events over a cycle. The electrical amplifier has incorporated in it an integrating circuit which electrically alters the grid voltage on the third stage to make it vary with pressure directly. Thus at the throw of a switch, either of two types of indicator card can be screened.

Timing and mechanical synchronization of the diagram with the engine are obtained by use of a commutator on the crankshaft. The point of ignition is obtained by coupling from the spark primary to the last stage of the amplifier. Photographic recording of the diagrams has been accomplished through cooperation with Professor Draper. For his latest work on detonation the latter has constructed a cathode-ray photographic recorder consisting of two five-inch tubes, and two totally-reflecting quartz prisms which focus the records on the respective tubes through a common lens onto a single strip film. By use of this apparatus simultaneous records of direct pressure and rate of change conditions can be photographed from a single pressure unit, by the use of an auxiliary amplifier of straight-forward design.

Department of English and History

THE research activities of the Department of English and History are, for the most part, confined to the fields of economic and social history. Professor Roberts and Professor Bridenbaugh are preparing papers to be presented at the annual meeting of the American Historical Association at Providence, Rhode Island, in December.

Mr. Watson is constructing for the Boston Port Authority a relief model of Boston Harbor. The completed model will show not only the topography of the harbor, but also the character and quantity of the important exports and imports.

Professor Roberts is working on his book, *The Cult of Stability, 1715–1740*, which will be published as one of a twenty-volume series, *The Rise of Modern Europe*, edited by Professor William L. Langer of Harvard. Professor Roberts has also in preparation a new chapter for the revised edition of Ploetz' *Epitome of History*, to be published next year by Houghton Mifflin and Co.

Professor Greene has completed a novel, the setting of which is in a New England mill town. He is now writing another novel. Professor Woodbury is preparing a biography of one of the important nineteenth-century figures in American science. Professor Fassett is continuing his study of the origin and development of the manufacture of glass in North America, as well as extending his previous work on the history of newspapers and on the theory of rhetoric. Professor Bridenbaugh's work on the development of American urban society from 1625 to 1776, and Professor Lawrence's study of the beginnings of the oil industry in the United States have reached the stage of final revision.

Professor Pearson's biography of the late President Maclaurin of Technology, which is nearly ready for publication, will certainly be of particular interest to Technology men.

ENGINES

(*Continued from page 160*)

power engine for light planes, the Warner seven-cylinder radial, and the Ranger inverted-in-line six. The latter engine is particularly attractive for the private owner on account of its relative freedom from vibration and its small amount of interference with forward vision in a tractor airplane.

In the second classification first cost is relatively unimportant, and no expense is spared to obtain the utmost reliability, the highest possible power output for take-off, and the lowest possible fuel consumption at the cruising speed. American engines in this class are nearly all air-cooled and of radial form. Typical examples are the Wright "Cyclone" nine-cylinder radial and the Pratt & Whitney "Twin Wasp" fourteen-cylinder double-row radial, both of which have maximum take-off ratings of 1000 horsepower and a cruising fuel consumption well below one-half pound per horsepower-hour. Such engines represent very significant engineering achievement, especially when the very high specific stresses to which the parts are subjected are considered in connection with the high degree of reliability and long life which such engines have demonstrated in actual service.

In Europe, in addition to many air-cooled radial engines similar to those already mentioned, liquid-cooled engines such as the Rolls-Royce and Hispano-Suiza are still widely used.

There has been a long-extended controversy among aeronautical engineers as to the relative merits of air-cooled and liquid-cooled airplane engines. In America, the lighter weight of the air-cooled power plant, and its freedom from the mechanical complications and greater cost of maintenance of a liquid-cooling system, has been considered sufficient to offset the disadvantages of the large cross-sectional area of the radial engine and its slightly higher drag as compared with the corresponding liquid-cooled engine (even if the latter is equipped with the most highly-refined type of radiator system). The continued increase in the relative number of air-cooled engines in use in Europe tends to indicate that the American position in the controversy is justified, at least for the present.

No article on the subject of airplane engines would be complete without considering some of the unusual types which are in the experimental stage. One group of these fall under the classification of engines using an abnormally large number of small cylinders, and running at very high crankshaft speeds. The Napier "Dagger" engine is an example of this. Whether or not such engines will prove to be of sufficient merit to justify wide use, remains to be proved. The other unusual type which is receiving much attention at the present time is represented by the compression-ignition, or so-called "Diesel" engine. The use of the Diesel cycle involves certain very important disadvantages, chief among which is a high ratio of maximum to mean cylinder pressure, which requires a heavier engine construction for the same output, other things being equal. To offset this is the possibility of securing lower cruising fuel consumption with this type of engine. However, improvements in the fuel economy of the spark-ignition engine have been so great recently that the margin by which the Diesel engine leads the spark-ignition engine in this respect is surprisingly small. Whether a saving in fuel weight sufficient to justify the increase in engine weight can be obtained in actual service, has yet to be proved by long experience. At any rate, it appears that the Diesel power plant is of interest only in the larger sizes and for relatively long flights. The only example of a Diesel engine in wide use is the case of the Junkers opposed-piston double-crankshaft engine. This engine is already in use for large commercial airplanes in Germany, and the progress of its development is being watched with great interest all over the world.

A glance into the immediate future in the airplane engine field indicates that radical changes in basic principle are very unlikely. While the possibilities of the "gas-turbine" and the "jet-propulsion" engine are interesting, such grave practical difficulties stand in the way of their application that this writer does not expect such devices to invade the field of airplane propulsion for a very long time. The steam power plant is inherently unsuited for aircraft propulsion on account of the fact that a high percentage of the heat developed during combustion must be dissipated in some kind of a radiator or condenser. The weight and drag of a condenser of requisite size would be so large as to put the steam plant at a tremendous disadvantage even if the engine and boiler equipment could be made light and efficient.

—*Courtesy Continental Motor Co.*

40 horsepower Continental A40

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AIRCRAFT MANUFACTURERS

(*Continued from page 167*)

St. Louis has a number of well known manufacturing concerns, including Lambert Aircraft (Monocoupe) and Curtiss-Wright. Monocoupes have long been known as private owner and racing planes. A number of records have been set by them. In addition to the familiar two-place, high-wing cabin ships, the company recently brought out a series of low-wing models. Most interesting is a twin-engined (Lambert) four- or five-place cabin plane for light feeder service and general charter work.

Curtiss-Wright's St. Louis plant was the home of the Condor, until recently used for both military and commercial purposes, the last of our large biplanes. More recently, the Coupe, a low-wing, all-metal ship to meet the Department of Commerce private-owner specifications has been turned out. Most recent is the C-W 19-R, an open-cockpit two-seater with both sport and military applications. The Sport and the Speedwing, open-cockpit biplanes for two or three are also still available to order. Widely circulated in the industry is the rumor of a large transport with sealed cabin for sub-stratosphere work in process of design. Significant perhaps of a reviving interest in the transport field is the appointment of Charles France, formerly operations manager for Eastern Air and Western Air Express, to take charge of this unit.

Fahlin Manufacturing Corporation of Marshall (Mo.) last year developed the Plymacoupe, a high-wing cabin monoplane powered with a modified Plymouth automobile engine. This machine was a part of the Department of Commerce light plane development program.

Another company, Arrow Aircraft of Lincoln, Nebraska, also turned out a ship with automotive power for the same requirement. The low-wing Arrow F is fitted with a modified Ford engine, and sells for $1500.

Consistent builder of light airplanes to fit the average man's pocketbook is Aeronautical Corporation, at Cincinnati. Aeronca airplanes, both on wheels and on floats, have had wide acceptance over many years. The C-3, a high wing monoplane with enclosed cockpit for two, seated side by side, is a familiar sight on many an airport. Latest is a low-wing monoplane of higher horsepower, greater performance, which has proven successful both as a land and as a sea-plane.

E. M. (Matty) Laird, one of the real oldtimers in the business, is still building airplanes at his shop in Chicago. He has two designs available—a six-place cabin sesqui-plane said to be good for 200 miles per hour and a three-place open-cockpit biplane of conventional type.

Among the largest manufacturers in the Middle West is Stinson at Wayne, Mich. Stinson is interested in three fields at present, the single-engined ship for the private and industrial owner (the well-known Reliant); the two-engined type for

(*Continued on page 180*)

Model Gasoline Airplanes

COMPLETE KITS

Red Zephyr, 6 ft. span..... $5.95
Miss America, 7 ft. span..... 9.50

FACTORY TESTED GASOLINE MOTORS

Factory Tested Gasoline Motors

Brown, Jr., Approx. 1/5 h.p. complete..... $21.50
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AIRCRAFT MANUFACTURERS

(*Continued from page 179*)

executives, light transport, or feeder service (the Model B), and the three-engined transport, the Model A. The old Model T transports, and the later Model U's (both three-engined) can still be seen on certain airlines. The former built up quite a reputation on the Ludington "Every-hour-on-the-hour" service between New York and Washington. As Stinson is a Cord affiliate, Lycoming engines and Smith controllable propellers are usually to be found on board. Typical Stinson construction on all types includes welded-steel tube frames and fabric covering.

Chief competitor of Stinson (in the Reliant class) is Waco at Troy, Ohio. Waco has stuck consistently to biplanes, and now produces four types, three of them in the cabin class (for five) and two open-cockpit types (for two). Performances vary with the power plants installed. Structurally, fuselages are of steel tube, welded; wings are wood panel; the whole is fabric covered. The open F series is of the sport type. The open D class is fitted with engines up to 400 horsepower, and has considerably better performance than any of the others.

Most phenomenal growth in many respects is that of Taylor Aircraft of Bradford, Pa. This concern has been manufacturing "Cubs"—a high-wing, tandem four-seater with Continental A-40 engine, for a number of years. Through the depression, sales were on a very modest scale, but in 1935 deliveries totaled some 219. In 1936, however, sales jumped so that it seems probable that over 500 Cubs will find their way into the hands of private owners and flying services this year. This growth has prompted the placing of the largest peacetime engine order known for aircraft components for civil use. Some 1400 Continentals are on the books for early delivery. The Bradford plant is working night and day on orders. At one period during the past summer, Cubs were coming off the production line at the rate of 18 a week. The factory has been more than doubled in size in the past twelve months. A recent substantial price reduction brings the Silver Cub cost to $1270.

C. G. Taylor, designer of the Cub, recently severed connections with his old company and formed a new set-up,—Taylorcraft. He settled for a while on the Pittsburgh-Butler Airport, later moving to Alliance, Ohio, into the plant of the old Hess Company. His new ship, the Taylorcraft, now in production is slightly larger than the Cub, is arranged for side-by-side seating, and has a pleasing, automobile-like interior finish. It is also powered by the four-cylinder Continental.

To prove the claim that all the important units are not on the Pacific Coast one should pay a visit to Hartford, headquarters of United Aircraft's manufacturing division. One of the largest and most beautiful plants and flying fields in the world is to be found on the east bank of the Connecticut. True, Chance-Vought's aircraft plant is not the largest unit of the group, but it is far from being overshadowed by the huge Pratt & Whitney engine plant, and the rapidly expanding propeller plant of Hamilton-Standard. From Chance-Vought have come ships that have formed the backbone of the "eyes-of-the-fleet" squadron for years. Corsairs are found in every flight deck and in many a catapult complement.

Bridgeport, forty miles to the south, is another center of activity, for from Sikorsky's plant on the bank of the Housatonic have come most of the giant Clippers for Pan American's world-wide services. Current production includes two types, the new twenty-one ton S42A, refinement of the Pan American Clipper type that pioneered the Pacific routes, and the S-43 amphibion, a twenty-two passenger machine of high efficiency that is being widely adopted on routes all over the world where overland and over-water flights are a regular part of the program. Rumors are current of design work at Bridgeport on new ships of one hundred tons gross and better. Mr. Sikorsky has long been a student of large aircraft, and may be expected to be heard from in the near future.

Following the coastline southward we come to Farmingdale, Long Island, where Seversky, Grumman, and Fairchild Engines now hold forth. As this is written the future status of Farmingdale is in some doubt. Grumman is rumored to be seeking expanded facilities to provide greater capacity for production of its line of Navy shipboard fighting planes. Seversky is ambitious to obtain the entire plant capacity at Farmingdale in anticipation of still greater orders from the Army for basic trainers and high-performance pursuit ships. Whether or not Fairchild will continue to make its Ranger inverted in-line engines at the Farmingdale plant is yet to be decided. Fairchild's airplane factory (formerly the Kreider-Reisner plant) is in Hagerstown, Md. Some economies might be made by consolidating engine and airplane manufacturing facilities at either Hagerstown or Farmingdale.

Further down the coast, at Wilmington, Del., is the factory whose products are dedicated to the design philosophy of

(*Continued on page 181*)

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AIRCRAFT MANUFACTURERS

(*Continued from page 180*)

Guiseppe Bellanca. It is the birthplace of many record breakers. The overall efficiency, long range, and heavy load carrying characteristics of Bellanca ships have made them popular not only where endurance records are at stake, but in commercial operations over undeveloped country where planes-of-all-work are a necessity.

One of the most completely equipped factories in the east is that of the Glenn L. Martin Company near Baltimore, whence came the Clippers now plying regularly across the Pacific Ocean. But in recent years Martin activity has been largely military. With a long tradition of bomber building behind it, the company has supplied the Air Corps with large numbers of these ships. There is, however, a persistent rumor that the design of a large transport plane is now on Martin drawing boards.

Among the builders of small craft on the Atlantic coast are Luscombe and Viking. Luscombe at Trenton, N. J., makes the "Phantom," high-performance, two-place, all-metal monoplane. At New Haven, Conn., Viking is now making small flying boats for the Coast Guard and will build Kitty Hawk biplanes on order.

This is the American aircraft manufacturing industry at the moment. Enough has been given, to show that our aircraft industry is not only of national importance, but is national in its physical proportions. Its growth is now under way again, not on the mushroom basis of 1927–29, but on solid economic grounds.

Douglas DC-3

AIRCRAFT INSTRUMENTS

(*Continued from page 171*)

several millimeters it is necessary to set the altimeter readings for barometric pressure before the altimeter can be used for landing purposes. This adjustment is carried out by turning the knob just below the dial until the figures of the small counter read the barometric pressure in inches of mercury.

Since an accurate setting of the altimeter requires a knowledge of barometric pressure, radio communication with a ground station is necessary before the actual height of an airplane above the ground can be determined. Even if the barometric pressure adjustment is correct, the airplane position and the map elevation at the given point must be known to make a definite estimate of altitude. This limitation of the barometric altimeter has caused several bad accidents in the past so there is a pressing need for a device to measure absolute altitude directly. A number of these instruments have been developed to work on the basis of radio or sound waves reflected from the ground to a receiver in the airplane. Up to the present time these altimeters have been relatively large in size and required too much of the pilots attention during operation for them to be adopted as standard equipment.

The magnetic compass supplies the only indication of direction that does not depend upon external visibility or communication with the ground. Since safe flight operations require accurate control of direction, the compass is an essential instrument in all airplanes. Unfortunately the conventional compass has such bad errors during turns and on certain courses that it is an unsatisfactory instrument for blind flying.

(*Continued on page 182*)

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AIRCRAFT INSTRUMENTS

(*Continued from page 181*)

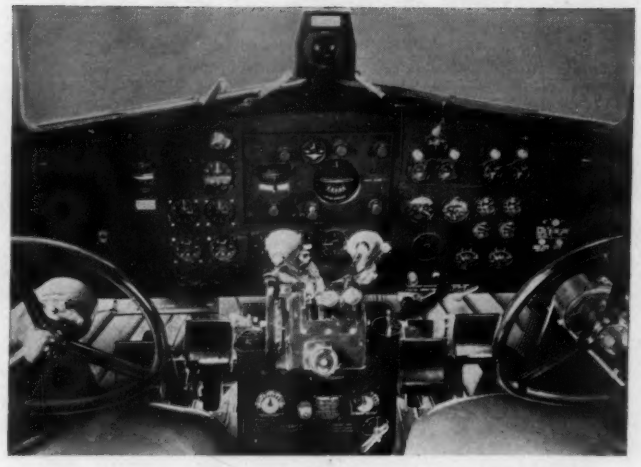
This limitation of the compass has furnished inspiration for gyroscopic instruments such as the Pioneer Turn Indicator which shows the rate of a turn and the Sperry Directional Gyro. This instrument is shown in figure 2.

The Directional Gyro is essentially a freely supported rotor which spins at such high speed that it moves very slowly under the torques due to the supports. The direction of the rotor axis can be set to any desired direction by an adjusting knob and will maintain this direction for considerable periods of time without the errors of a magnetic compass.

The ball bank indicator is a damped pendulum so mounted that it shows the direction of the resultant force on the airplane. When the airplane is flying straight and level, this instrument will also show the angle of the wings with respect to the horizontal. In rough air or during a turn, the ball bank indicator will not give a reliable indication of bank. This difficulty is overcome by a third gyroscopic instrument called the Sperry Artificial Horizon which is shown in figure 3.

In the Artificial Horizon the direction of the axis of a small high speed rotor is controlled by pendulous vanes through the medium of four air jets. These air jets act to move the rotor axis in line with the average direction of resultant force on the airplane. Since the air jet torque is very weak the rotor axis moves very slowly under disturbing influences and will be very nearly along the vertical when it reaches a position of equilibrium. The vertical rotor axis is used to control a reference bar which remains always parallel to the real horizon and can be used to keep an airplane properly orientated in pitch and roll.

Radio has supplied an indespensable link in the chain of equipment for blind flying. As a means of communication it is used to transmit instructions and weather information to the pilot in flight. The radio beams between the principal airports make it easier to follow straight connecting courses with blind flying technique than to use the ordinary methods involving external visual references. Recent developments in radio compasses have made it possible to fly directly toward any selected radio station and to determine airplane positions by triangulation on two or more stations. Aside from the course



—*Courtesy Sperry Co.*

Fig. 5—Instrument panel of Douglas DC-3.

information which it supplies, radio equipment is necessary as a means for aerial traffic control. A pilot who arrives at a large air terminal without his radio in operation to receive landing instructions may cause dangerous complications. The functions of radio in aircraft are being rapidly extended to include an essential role in blind landing routines which can be used when necessary in normal airline operations. Future applications of the new short wave technique may soon make it possible for a pilot not only to measure his altitude above the earth but also to look ahead for dangerous obstacles.

All the essential requirements of safe flying are met by the present day instrument equipment, but the pilot's duties are so exacting that developments will certainly take the direction of simpler indicators and more automatic control devices. When the remaining problems are examined in the light of the obstacles to blind flight which have already been overcome, the complete triumph of instruments over the limitations of a human pilot's senses seems a relatively small step in advance of the art as it is used today.

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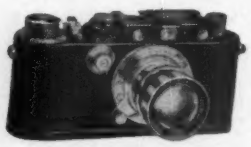

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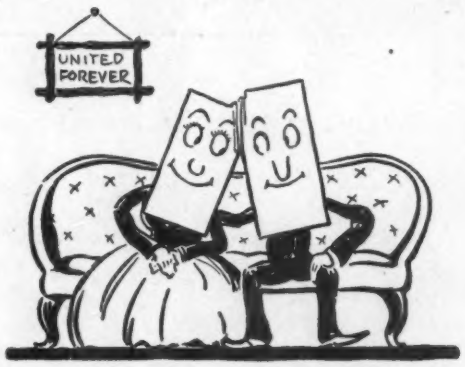
G-E *Campus News*

NUMBER 7000

JUST as if timed to take part in the 25th birthday celebration of the General Electric shops in Erie, Pa., Locomotive Number 7000 recently bowed its way out of its shed and took a brilliant turn on the test track.

The first of Number 7000's predecessors was begun in Erie in 1911, or just 25 years after electrical manufacture had commenced in Schenectady. Since that time locomotives weighing from 1½ to 300 tons have been turned out to improve haulage electrically. This range includes types for every sort of service—straight electric with trolley pole or third-rail shoe, battery types, internal-combustion engines, and combinations of different designs.

The Erie plant is notable for its contributions to practically every phase of modern electric transportation. The electrification of terminals and railroads has been accomplished largely with Erie equipment. Many of the new high-speed trains, which have aroused so much interest in rail travel, and many urban transit vehicles, such as street cars, trackless trolley coaches, and diesel-electric buses, likewise use Erie equipment.

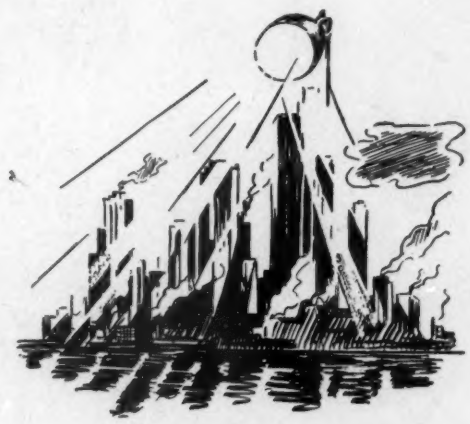


FIFTY YEARS OF WELDED BLISS

TWO pieces of metal were joined in "weldlock" fifty years ago. That was in 1886, when Professor Elihu Thomson, one of America's greatest pioneers in the field of electrical science and co-founder of the General Electric Company, invented resistance welding—fusing metals by placing them in contact and passing an electric current through them.

To mark the golden anniversary and to honor the man who officiated at the "ceremony," the Detroit Section of the American Welding Society dedicated a recent program to Professor Thomson's invention.

The years have seen resistance welding develop from its purely experimental stage into a process of metal fabrication that is wide in application. Metal radio and industrial tubes and parts, automobile bodies, the high-strength aluminum alloys used in aircraft, farm implements, the new lightweight railway equipment—all are fabricated by resistance welding.



SUNSHINE IN MANHATTAN

AT last there is sunshine—sunshine for those who spend so much of their hurried lives in the shadows of Manhattan's financial district. For in his new downtown recreation and health center—largest of its kind in the world—Artie McGovern, famous trainer and physical director, has equipped both the hot room and gymnasium with ultraviolet sunlamps.

Installed by General Electric engineers in the form of 26 ceiling units—probably the largest installation ever made in a single location—they not only afford health-giving artificial sunshine but are the sole means of illuminating the two rooms.

This installation marks another step forward in the field of lighting. The development of better lamps to sell at greatly reduced prices, the campaign for safety on the highway by means of improved highway lighting, the "Better Light—Better Sight" movement for the protection of eyesight, and the search for methods to improve general health have all been given strong impetus through the efforts of the General Electric Company.

96-340DH

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